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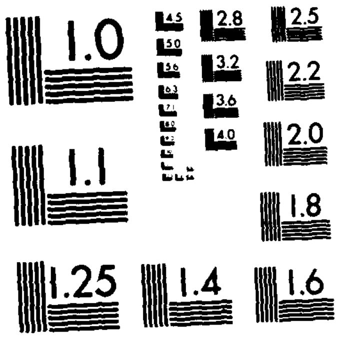

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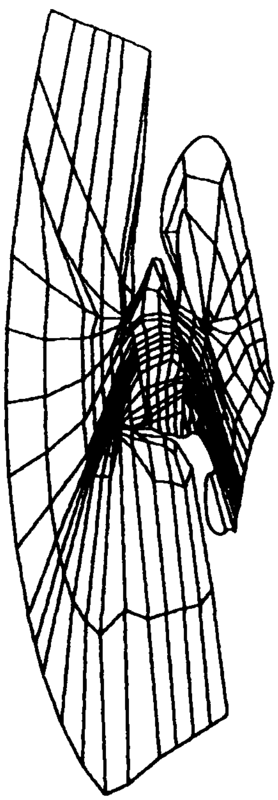

HYDRAULICS LABORATORY

AD-A134 392

TECHNICAL REPORT HL-83-16

COLUMBIA RIVER ESTUARY HYBRID MODEL STUDIES

Report 4
ENTRANCE CHANNEL TESTS

by

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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

A hybrid modeling approach using a fixed-bed physical model, numerical models, and analytical techniques was used to study navigation channel shoaling at the mouth of the Columbia River. Sixteen plans for reducing channel maintenance dredging at the existing 48-ft depth and at 55- and 60-ft depths were tested. Effects of the plans on tides and currents were found to be subtle. Nondeepening plans had minor effects on salinity intrusion while

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ABSTRACT (Continued).

channel deepening increased salinities by 1 to 6 ppt up to about mile 18. Only one structural plan reduced shoaling below base conditions for the 48-ft channel. Channel deepening increased shoaling considerably.

PREFACE

The work described herein was performed by the U. S. Army Engineer Waterways Experiment Station (WES) with funding by the U. S. Army Engineer District, Portland. The numerical models STUDH and RMA-2V and their several utility computer codes were developed with funds from this project and the Chief of Engineers Improvement of Operations and Maintenance Techniques research program.

Personnel of the WES Hydraulics Laboratory performed this study under the direction of Messrs. H. B. Simmons, Chief of the Hydraulics Laboratory, F. A. Herrmann, Jr., Assistant Chief of the Hydraulics Laboratory, R. A. Sager, Chief of the Estuaries Division, and G. M. Fisackerly, Chief of the Harbor Entrance Branch. Mr. W. H. McAnally, Jr., was project manager, Mr. N. J. Brogdon was physical model project engineer, and Mr. J. P. Stewart was numerical model project engineer. Messrs. D. M. White and B. Brown, Jr., were senior project technicians. Messrs. McAnally, Brogdon, and Stewart prepared this report.

The many contributions of Messrs. W. A. Thomas, WES, H. D. Herndon, project monitor for the Portland District, and J. G. Oliver, North Pacific Division, are gratefully acknowledged.

Commanders and Directors of WES during this study were COL John L. Cannon, CE, COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
cubic feet per second	0.02831685	cubic metres per second
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
feet per second	0.3048	metres per second
miles (U. S. statute)	1.609344	kilometres

COLUMBIA RIVER ESTUARY HYBRID MODEL STUDIES

ENTRANCE CHANNEL TESTS

PART I: INTRODUCTION

Objectives

1. The hybrid model studies of the Columbia River estuary entrance were performed to determine the effects of several potential improvement plans on navigation channel shoaling and tides, currents, and salinities in the estuary. This report describes the plans tested and presents model results.

Background

2. The U. S. Army Engineer District, Portland, dredges about 4 million cu yd (mcy)* of sediment from the Columbia River estuary entrance channel each year. Hybrid modeling studies have been performed to provide information that will help to design measures to reduce present shoaling rates and minimize shoaling if the channel is deepened.

3. The tests described herein are part of a complete modeling program for the estuary. Other work performed in support of this program is reported separately. McAnally and Donnell (in preparation) described the field data collection effort, and Donnell and McAnally (in preparation) have analyzed a portion of the field data. A detailed description of the modeling method and verification of the entrance models is given by McAnally et al. (in preparation). Subsequent U. S. Army Engineer Waterways Experiment Station (WES) reports will present results of other model studies of the estuary.

Modeling Technique

4. The Columbia hybrid modeling system developed at WES consists of a large-scale physical model of the estuary, a numerical model for wave

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

propagation, a numerical, two-dimensional hydrodynamic model (RMA-2V), a numerical, two-dimensional sediment transport model (STUDH), a number of analytical techniques, and a data management system. The hybrid method employs each of these tools in an integrated fashion to provide predictions of estuarine behavior that are superior to those of any single model, and represents the most sophisticated tool available today for solution of estuarine sedimentation problems.

5. Briefly, the hybrid method employed the physical model to predict water levels and current velocities caused by tides, riverflow, and salinity-induced density currents. The numerical hydrodynamic model interpolated the water levels and currents in space to provide input data to the numerical sediment model. The wave model refracted and diffracted deepwater ocean waves into the entrance area, and an analytical technique was used to predict longshore currents. Five combinations of waves and current data were used to drive the sediment model.

PART II: TEST DESCRIPTIONS

6. Fifteen entrance channel (Figure 1) plans were tested involving three channel design depths--48, 55, and 60 ft--and several structural arrangements. A summary of the plans is given in Table 1. Hydrodynamic, shoaling, and salinity tests were performed for existing conditions and each plan.

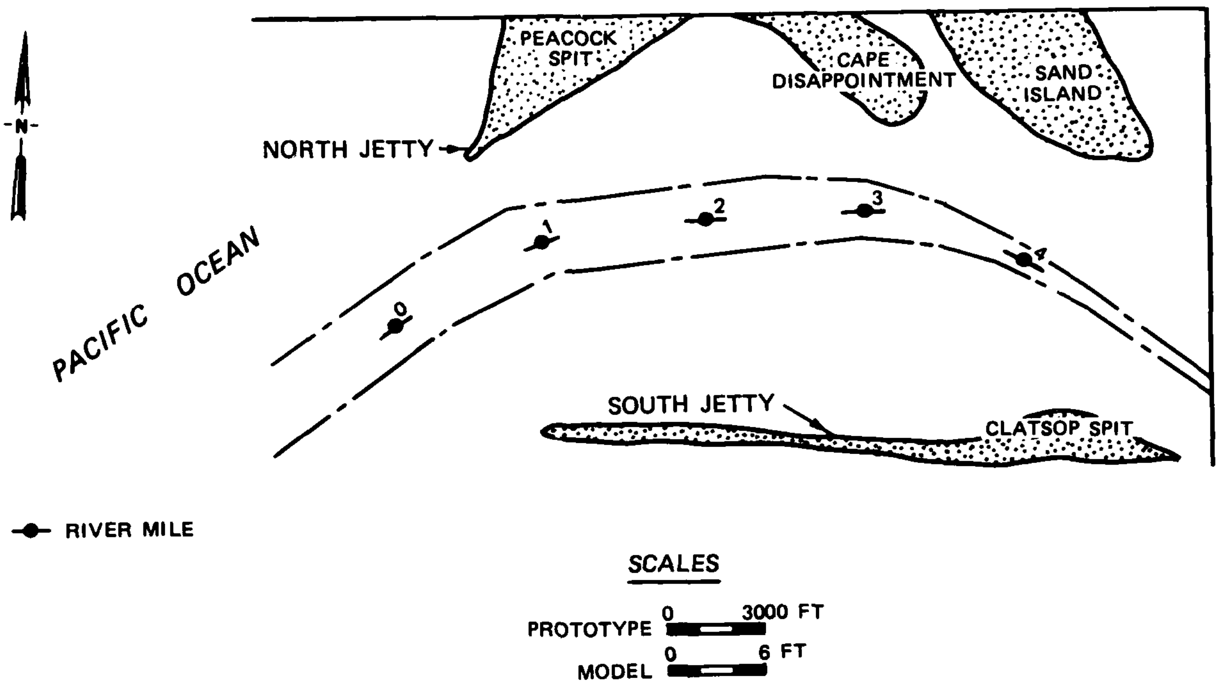


Figure 1. Mouth of the Columbia River entrance channel

Test Conditions

7. All of the above tests were conducted with a mean tide (8.5-ft range at the north jetty) and a source salinity concentration of 33.0 ppt. Freshwater discharges at the upper end of the physical model (Columbia River mile 53) varied in the early stages of plan testing from 140,000 to 550,000 cfs with intermediate discharges of 220,000 and 300,000 cfs. North jetty plan testing was conducted with each of the four above discharges; however, midway through the south jetty test series it was decided (based primarily on time and cost) to test with a single freshwater inflow of 300,000 cfs. Thereafter, all hydraulic tests were conducted for only the 300,000-cfs freshwater inflow.

All salinity tests reported herein were conducted with a 140,000-cfs freshwater inflow condition.

8. The sediment model was run for five events (combinations of hydrodynamic conditions that were used to produce a typical year's shoaling results. The statistical derivation of the events and their accumulation into a year are described in the verification report (McAnally et al., in preparation). The base and plan tests were performed with the same set of events used in the verification tests. The events were for a river discharge (at river mile 53) of 300,000 cfs, a tide range of 8.5 ft at the north jetty, and wave conditions shown in the following tabulation.

Wave Height ft	Wave Direction	Wave Period sec	Duration days
--	None	--	139
10	SW	10	56
10	W	10	112
10	NW	10	57
20	SW	15	1

9. As was done in the model verification, each of the above events was run separately in the numerical model, then the results from each were assembled by the computer code ACE to yield a typical year's shoaling and dredging. The physical and numerical models were tested with the design channel depth (48, 55, or 60 ft) installed. During event accumulation by ACE, 2 ft overdepth dredging was applied.

Plans Tested

48-ft channel tests

10. The existing 48-ft-deep (mllw) by 2,640-ft-wide channel along with the existing north and south jetty conditions was installed during both verification and base tests. Neither the north nor south jetties have been built to their full authorized length. Both jetties have suffered some deterioration resulting in still shorter lengths of continuous jetty. For the base tests described here, the jetties were constructed to conform with conditions surveyed in 1976. In addition to the base test (existing channel and jetties), several proposed plans were conducted with the existing 48-ft channel

condition. These included: (a) north jetty authorized length (Plan A1); (b) north jetty degraded length (Plan A2); (c) south jetty authorized length (Plan B1); (d) south jetty degraded length (Plan B2); (e) south jetty partial rehabilitation (Plan B3); and (f) two jetty B plans (Plans F0 and F1). North and south jetty plans are shown in Plates 1 and 2, respectively. North jetty Plan A1 extended the existing jetty approximately 1,372 ft seaward, while Plan A2 reduced the existing jetty length by about 597 ft. North jetty Plans B1 and B3 extended the jetty seaward from existing conditions by about 3,497 ft and 1,745 ft, respectively. Plan B2 reduced the effective length of the jetty by about 1,719 ft. The jetty B plans were as follows: (a) jetty B with a crown elevation above mhhw (+18 ft mllw) and a length of 4,106 ft (Plan F0); and (b) jetty B with a crown elevation submerged to elevation -10 ft mllw and a length of 4,106 ft (Plan F1). Dimensions and other information on the above jetty B plans are shown in Plate 3. Jetty B is authorized but not built.

55-ft channel tests

11. The 55-ft channel study involved three deepening only plans (Plate 4), one deepening and realignment plan, and three jetty B plans. Plan C0 was the basic 55-ft channel and varied from the authorized 48-ft channel only in depth. The second 55-ft channel (Plan C1) was the same as Plan C0 from the seaward end of the channel to mile 1, at which point the channel began a transition from a 55- to a 48-ft depth. The transition from the 55-ft depth to the 48-ft depth was achieved at a rate of a 1-ft decrease in depth for every 200 ft along the channel axis, or a total distance of 1,400 ft (prototype). Alignment and width remained the same as the authorized 48-ft channel. The third 55-ft channel plan (Plan C2) involved reducing the bottom width from 2,640 to 2,000 ft. The reduction in width was achieved by filling 640 ft on the south side of the base 55-ft channel to the projected elevation of shoaling that would occur without maintenance dredging.

12. The channel realignment plan (Plan I0) consisted of deepening the channel to 55 ft along the alignment shown in Plate 5. The farthest seaward bend in the channel (about mile 0.5) was moved 1,040 ft downstream and the outer portion of the channel was rotated northward 2°45'31".

13. The first of three 55-ft channel jetty B tests (Plate 6) was with the base 55-ft channel of Plan C0 and the full height and a 4,106-ft-long jetty B (Plan G0). The second 55-ft jetty B test consisted of the base 55-ft

channel, a revised jetty B, and a groin (Plan G1). The revised jetty B had a crown elevation of -10 ft mllw and was 300 ft shorter than in Plan G0. The 1,533-ft-long groin was parallel to and 4,500 ft seaward of jetty B. The third 55-ft channel and jetty B test (Plan G2) involved all the elements of Plan G1, together with the authorized south jetty.

60-ft channel tests

14. Two 60-ft channel conditions were tested as shown in Plate 7--the first or base condition was with the existing north and south jetty conditions and no structures installed (Plan H0); the second plan was a 60-ft channel together with a full length, submerged (-10 ft mllw) jetty B and the authorized south jetty (Plan H1). The alignment and width of the 60-ft channel were the same as the 48-ft-channel base condition (Plan A0). The alignment, length, and height of jetty B were the same as those in Plan F1.

Model Revisions

Physical model

15. The various channel plans were installed in the physical model by molding, in concrete, the specified nominal channel depth and alignment. Side slopes of 1V on 3H were used. Model jetties and groin were constructed of impermeable cement grout to design top elevations, side slopes, and alignments.

Numerical model grids

16. The several plans were represented in the wave model's uniform grid by the appropriate channel depths at computation points along the channel, and by representing structures as a line of land cells along the jetty alignments.

17. In the finite element grid (Figure 2) used by the numerical hydrodynamic and sediment models, the north and south jetties were represented as impermeable walls with flow immediately adjacent to the jetty permitted to be parallel to it (slip flow boundary). Elements near the ends of the north and south jetties were rearranged for each plan test so that the jetty tips were at the correct location as shown in Plates 1 and 2.

18. For the full height jetty B plans (Plans F0 and G0), the jetty was represented in the finite element grid by an impermeable wall with parallel flow like that used for the north and south jetties. For the submerged jetty B plans (Plans F1, G1, and H1), the jetty was represented by an additional row of water elements along the jetty alignment. Bottom elevations at

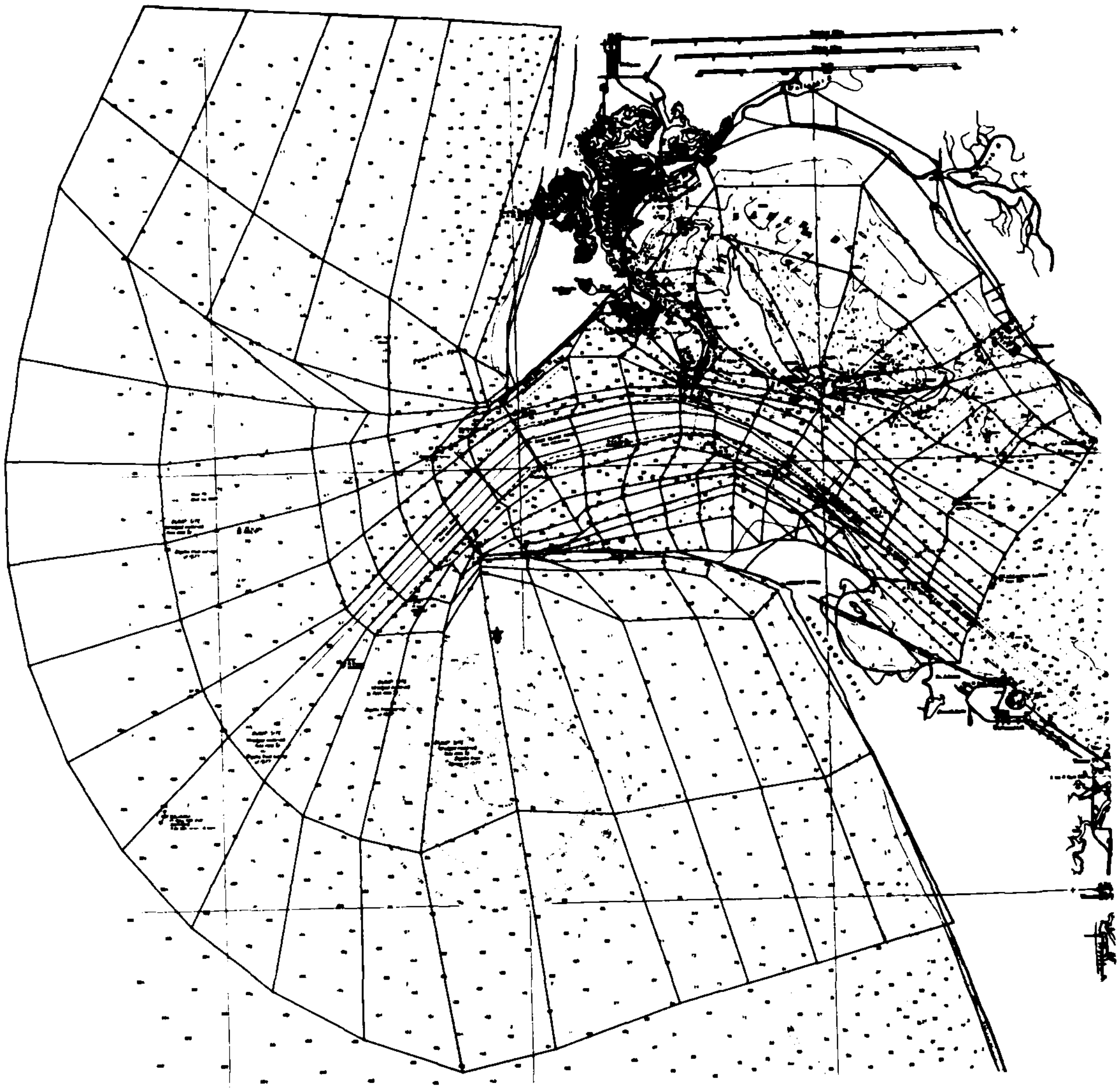


Figure 2. Finite element grid for numerical models

the nodes of the row of elements were set to -10 ft mllw. Since the numerical hydrodynamic model assumed that vertical accelerations were negligible and did not represent the jetty as a sharply rising structure, an additional measure was required to more properly represent the flow field over the jetty. The equation for flow over a weir was set equal to Manning's equation for flow across the row of jetty elements. The resulting expression was solved for values of Manning's roughness coefficient at a range of flows. From inspection of the range of coefficients, a Manning's n of 0.05 was selected and applied to the submerged jetty B elements for input to RMA-2V.

Miscellaneous Studies

19. The physical model was used to investigate several proposed plans other than those entrance channel plans described above. Data resulting from these miscellaneous studies were furnished to the Portland District office, often with little or no analysis by WES personnel. Data collected from the following miscellaneous studies are on file in the Portland District office and at WES and are not included in this report.

Price Island-Brookfield Dike study

20. Time-lapse photography of surface current patterns and subsurface current velocity measurements were made to determine the optimum dike field arrangement.

Chinook Dike study

21. Time-lapse photography was used to determine the effects on surface current patterns in the vicinity of Chinook Dike and the east entrance to Baker Bay as a result of removing Chinook Dike.

Dredge *Biddle* study

22. Time-lapse movies and photography were used to monitor and record the position of the dredge *Biddle* at given intervals of time after it collided with another ship, resulting in a loss of power and anchor. Tests were conducted with the *Biddle* released at two separate locations at several different times during the tidal cycle. The tide occurring at the time of the accident and approximate wave conditions were reproduced in the model for the tests.

Ilwaco Channel Dike study

23. Surface current pattern photographs showed effects of removing one groin and a section of another groin from the center of the Ilwaco Channel Dike.

Sand Island Gap closure study

24. Sand Island Gap was closed with a dike and surface current pattern photographs were obtained and compared with base conditions to determine the effects of the closure on current velocities and patterns throughout Baker Bay.

Dredged material disposal area sediment tracer tests

25. Time-lapse movies were made to trace the movement of simulated dredged material from several presently used and proposed disposal areas.

Areas investigated in the model included the following: areas C, D, E, and T, and proposed areas at jetty A, Tongue Point, and Astoria Bridge. Bottom depth current speed and direction were measured at each site to help define the direction of sediment movement from the sites.

PART III: TEST RESULTS AND ANALYSIS

Data Presented

26. Results of the model tests are presented as comparisons between model plan data and model base data. Tidal elevation time-histories from the physical model are presented for the north jetty (node 392), near Point Adams (node 54), and near Chinook (node 849) as shown in Figure 3. Current velocities from the physical model are given for three depths at two stations (nodes 127 and 286) on the navigation channel prism lines at the mouth, upstream in the navigation channel at node 160, and in the northern side channel at node 823--all shown in Figure 3. Minimum, maximum, and hourly salinities are presented for 14 stations (2-mile intervals) along the center line of the navigation channel, 8 stations along the thalweg of the north channel, and at 4 stations located in the entrances to Baker and Young's Bays. Salinity stations are also shown in Figure 3.

27. Bottom flow predominances for sta 127 and 286 are given in Table 2 for each plan tested. The flow predominance is expressed as a percent of total flow downstream. This parameter is obtained by first integrating the bottom velocity time-history to obtain the areas subtended by the ebb and flood portions of the curve. The percent downstream is then computed as 100 times the ratio of the area subtended by the ebb portion of the curve to the sum of the ebb and flood subtended areas of the curve. A value of 50 percent indicates balanced ebb and flood flows, a value less than 50 percent indicates predominantly flood flows, and a value greater than 50 percent indicates predominantly ebb flows.

28. Shoaling results from the numerical model are presented in the form of contour maps of bed change and volumes of shoaling material accumulating in those elements making up the navigation channel in the computational mesh. The computational mesh and the pertinent elements are shown in Figure 4.

Hydraulic Results (Physical Model)

48-ft channel tests

29. Effects of the north jetty, south jetty, and jetty B plans on tidal elevations and current velocities were measured in the physical model at the

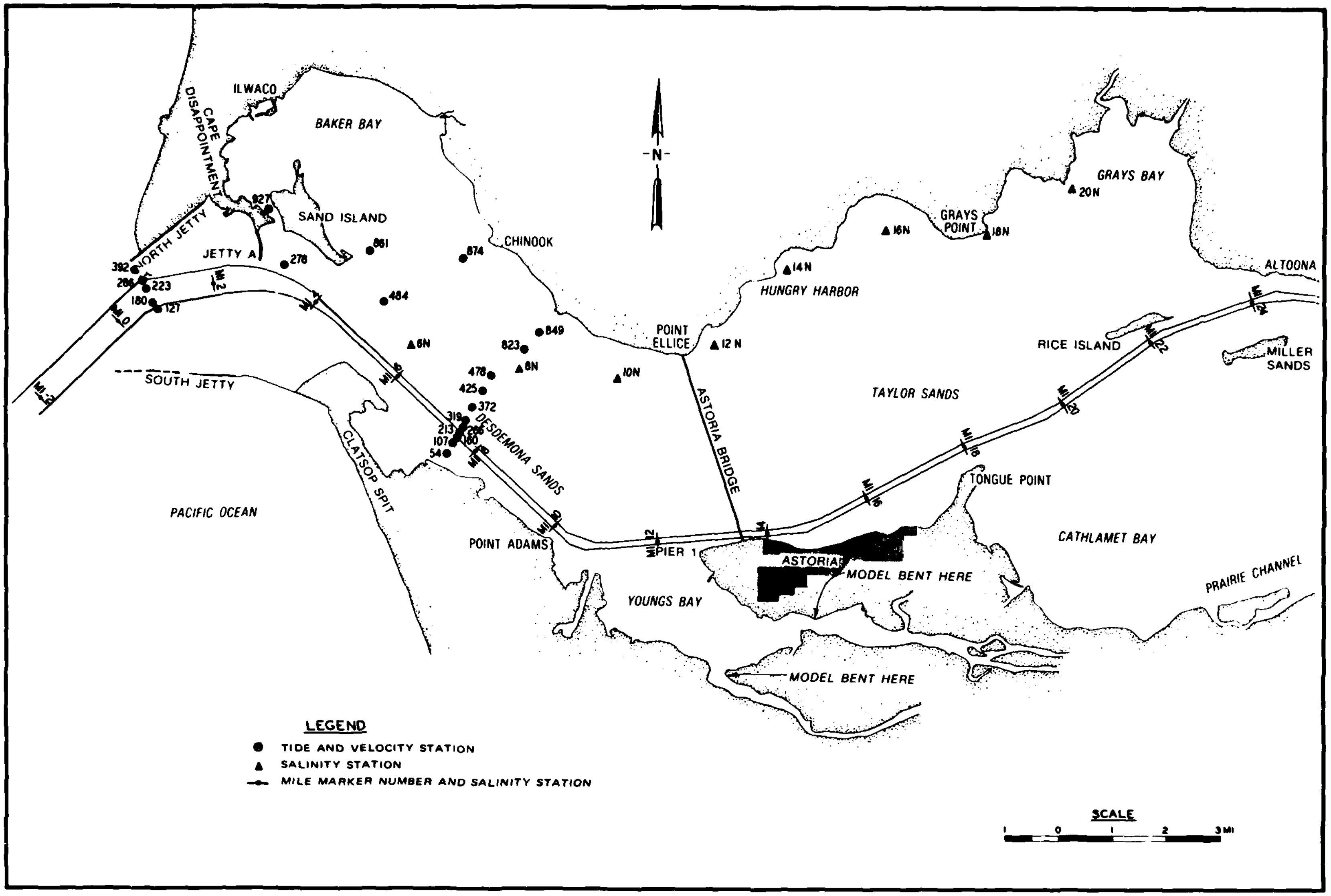


Figure 3. Station location map

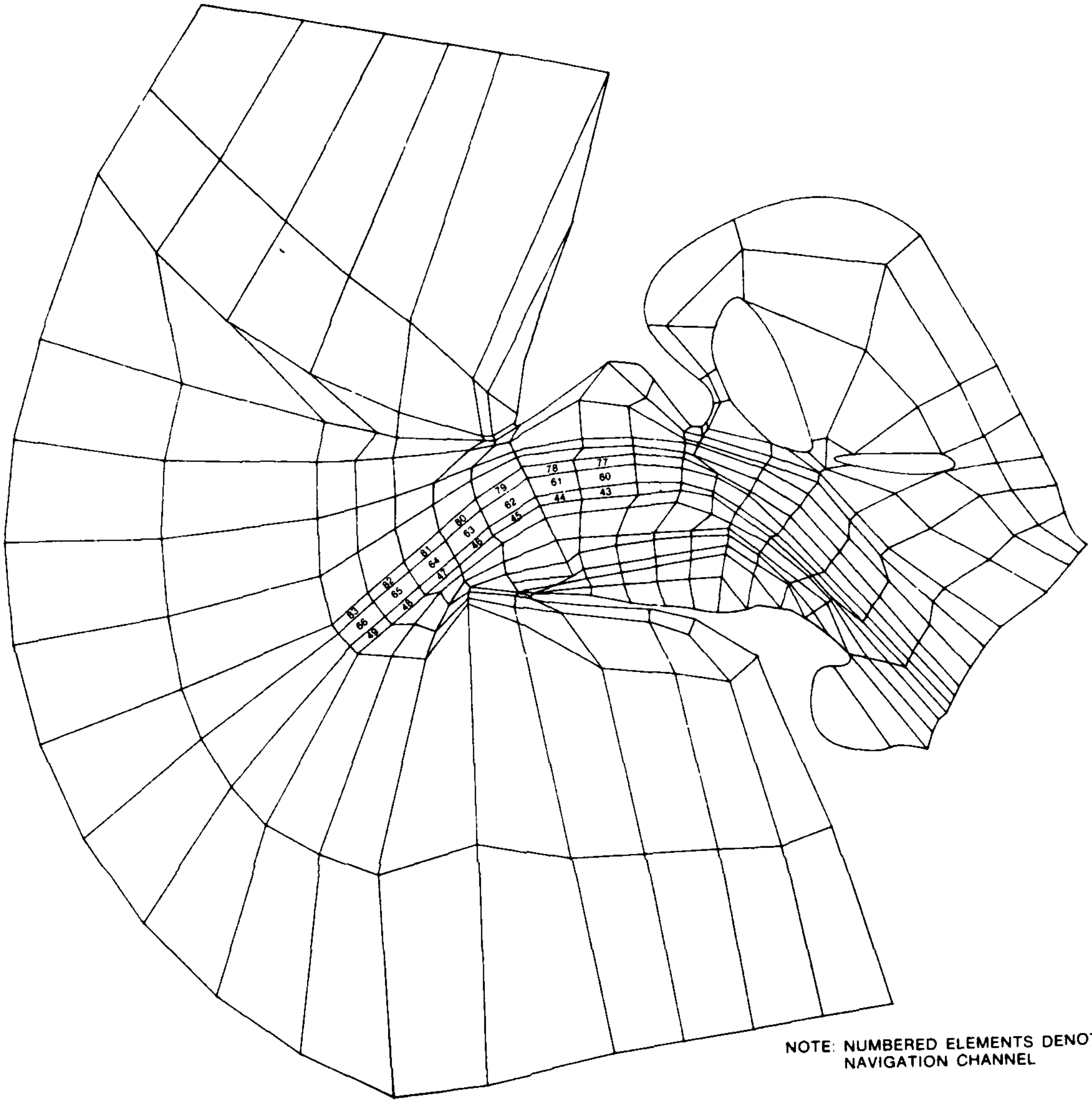


Figure 4. Computational mesh with navigation channel elements

stations shown in Figure 3. Data from all of these stations were used to drive the numerical model, and data from a few are presented in Plates 8-19 to illustrate plan effects.

30. North jetty plans. The three north jetty plans were so similar that after checking tides and currents near the jetty to determine that changes were minor, the physical model base test data were used at other locations to drive the numerical model for all three plans. Plate 8 shows that tidal elevations at sta 392, the only station measured, were essentially similar. Velocities at sta 286 (Plate 9) were also similar except for a brief period at each strength of flood when Plan A1 exhibited higher speeds than the

base and Plan A2 tests. Velocities were not measured at sta 127, 160, or 823. Bottom flow predominance for sta 826, shown in Table 2, did not change significantly in the north jetty plan tests.

31. South jetty studies. The three south jetty plans had minor impact on tidal elevations (Plate 10) with discernible differences only at sta 392, where a slight rise in mean tide level was observed for the plans and Plan B1 exhibited a 30-min phase lag in the ebb phase following both high waters. Sta 127 velocities (Plate 11) were not changed much except at the surface, where ebb velocities were higher for Plan B2 and lower for Plans B1 and B3. Thus the two longer south jetty plans reduced surface ebb velocities at sta 127. Velocities at sta 286 (Plate 13) showed effects of the plans, but the only consistent difference was at middepth, where Plan B3 exhibited higher ebb velocities. Sta 160 and 823 velocities were not affected by the plans. Bottom flow predominance at sta 127 and 286 (Table 2) show only minor differences between the plans, as one would expect from examining the velocity plots.

32. Jetty B plans. Tidal elevations at sta 392 (Plate 15) were somewhat higher for Plans F0 and F1 than for the base, similar to the south jetty plans. The other stations were unchanged. At sta 127 (Plate 16), Plan F0 exhibited consistently higher ebb velocities at both middepth and bottom while Plan F1 showed virtually no change. At sta 286 (Plate 18) the only noticeable differences were bottom ebb velocities lower than the base for both jetty B plans. Sta 160 (Plate 17) showed no significant changes, but sta 823 (Plate 19) surface ebb velocities were markedly smaller than the base for both plans.

33. Plan F0 caused a change in direction of the bottom flow predominance (Table 2) at sta 127, increasing it from 49 percent downstream to 57 percent downstream. In contrast, at sta 286 the bottom flow predominance decreased from 47 percent downstream to 33 percent for Plan F0 and 40 percent for Plan F1. This indicates that both plans reduced the net seaward transport of water in the north channel at sta 286.

55-ft channel tests

34. Hydraulic results for the 55-ft-deep entrance channel tests are given in Table 2 and Plates 20-34.

35. Nonstructural plans. Plans C0, C1, and C2 had negligible effect on tidal elevations as shown in Plate 20. At sta 127 (Plate 21), Plans C0 and C1 exhibited only slight decreases in ebb velocity; whereas Plan C2, in which the

depth at sta 127 decreased, showed an expected increase in ebb velocities but no real change in flood velocities. Sta 160 and 823 (Plates 22 and 24) experienced no significant change. Sta 286 (Plate 23) showed a slight reduction from base surface and bottom ebb velocities.

36. Bottom flow predominances (Table 2) did not change much at sta 127 and 286. Only the drop from 47 percent downstream to 35 percent at sta 286 for Plan C2 is large enough to demonstrate a definite change in flow.

37. Plan I0, the channel realignment plan, was plotted with the H-series plans to reduce the number of pages. Tides for Plan I0, plotted in Plate 30, are changed from the base only at sta 392, where elevations precede those of the base by about 1 hr and low waters are about 0.8 ft higher. There is no ready explanation for the phase shift, and considering the minor change in the channel, this result may be in error. Plan I0 velocities at sta 127 showed increased bottom ebb velocities (Plate 31), sta 160 showed no change (Plate 32), sta 286 (Plate 33) exhibited only minor differences, and sta 823 (Plate 34) experienced slightly increased velocities. As shown in Table 2, Plan I0 had essentially no effect on bottom flow predominances.

38. Structural plans. Tidal elevations and velocities for the G-series plans are plotted with Plan C0 results in Plates 25-29 to demonstrate the effect of the structural changes (jetty B and groin). Tides (Plate 25) were virtually unchanged at the upstream stations, but at sta 392, Plan G2 can be seen to shift tidal elevations forward by about 30 min and raise the elevation of higher high water. This was not observed in the F-series tests (jetty B with the 48-ft channel); therefore the change must be due to construction of the nearby groin. At sta 127 (Plate 26), the only notable change in velocities occurred with Plan G0, which increased ebb velocities at all depths, as did Plan F0, the comparable 48-ft channel test. Similarly, at sta 286 (Plate 28), both Plans F0 and G0 reduced bottom ebb velocities. At sta 160 (Plate 27), no velocity changes were observed while at sta 823 (Plate 29), a small reduction in surface and middepth ebb velocities occurred.

39. As shown in Table 2, Plan G0 had essentially the same effect on flow predominances as Plan F0--increasing the percent of total flow downstream to 56 percent at sta 127 and reducing it to 31 percent at sta 286. Plans G1 and G2 had a minor impact on flow predominances.

60-ft channel tests

40. Hydraulic results of the 60-ft channel studies are shown in

Plates 30-34. For the first time, tides at sta 54 and 849 are seen to have been affected by a plan. As shown in Plate 30, there is a slight but consistent increase in tidal elevations at both stations. At sta 392, plan elevations precede those of the base test by about 15 min, and the mean tide level elevation was raised by about half a foot. Bottom and middepth velocities at sta 127 (Plate 31) were reduced somewhat, particularly on ebb. Bottom and middepth ebb velocities were increased very slightly at sta 160 (Plate 32). At sta 286 (Plate 33), small differences in velocities were observed, with a slight trend toward reduced magnitudes. Plate 34 (sta 823) shows that ebb velocities at the middepth and bottom were increased over the base by the 60-ft channel plans. Surface and middepth flood velocities at sta 823 also were increased.

41. Table 2 shows that sta 127 flow predominances were reduced by the H plans, with the lowest downstream predominance of any plan tested (38 percent) recorded for Plan H0 at that station. Sta 286 predominances were unaffected by the plans.

Salinity Results

42. Effects of the various plans on salinity conditions are presented as time-averaged and extreme value profiles in Plates 35-76. Station locations are shown in Figure 3.

48-ft channel tests

43. Effects of the north jetty, south jetty, and jetty B plans on salinity values at 14 stations (2-mile intervals) along the center line of the navigation channel, 8 stations along the thalweg of the north channel, and 4 stations located in the entrances to Baker and Young's Bays are shown in Plates 35-55 and 70-76.

44. North jetty plans. Average salinities (average of surface, middepth, and bottom depth over the entire tidal cycle) along the navigation channel center line showed minor effects (Plate 35) resulting from the A-series plans. The largest changes in average salinity occurred between miles 2 and 10. Plan A1 caused a small increase in average salinity values (generally less than 1 ppt) from mile 2 to mile 6. The greatest increase was about 1 ppt at mile 4. The greatest impact for Plan A2 was at mile 10 with a 1.6 ppt increase. Plan A1 resulted in no salinity change upstream of mile 12,

but Plan A2 increased salinity by about 0.5 ppt from mile 12 to mile 18. Plate 36, average (over the tidal cycle) salinity profiles for surface, middepth, and bottom depths, shows a slight increase in vertical mixing in the entrance area for both plans (somewhat more change with Plan A1), as surface and middepth salinities were increased slightly while bottom salinities were decreased slightly.

45. Maximum and minimum salinity profiles (Plates 37 and 38) show, like average salinity values, that maximum effects occurred generally between miles 2 and 10. Plan A1 resulted in the greatest change--maximum salinity values were slightly greater than base (48-ft channel), while minimum salinity values were slightly lower than base. The upstream extent of salinity intrusion was unchanged by either plan.

46. Time and depth average salinity values along the thalweg of the north channel (Plate 39) showed a general increase of 1 to 2 ppt as a result of the north jetty plans; however, no apparent increase in salinity was evident above mile 16. At two points along the channel, Plan A1 showed small decreases in average salinity concentrations. Plan A2 effected a greater increase than did Plan A1, particularly at the middepth and bottom elevations (Plate 40). Plan A2 maximum salinity values (Plate 41) were generally greater than both base and Plan A1 at middepth and bottom elevations, while generally less than base and Plan A1 at the surface (thus indicating less mixing for Plan A2). Very little difference was noted in minimum salinity values for both plans; however, minimum salinities for Plan A1 were generally less than those for base and Plan A2.

47. South jetty plans. Maximum effects of the south jetty plans, like those of the north jetty, occurred in the entrance area and upstream to about mile 12. Time and depth average salinity values in the navigation channel (Plate 42) with each of the three plans installed were generally slightly greater than base conditions. Plan B1 (authorized length) resulted in average salinity values at four stations along the channel center line being lower than base conditions. Plan B2 resulted in two stations along the channel center line having lower average salinity values than base, while Plan B3 resulted in three locations along the channel having lower average salinities than base conditions. Plan B2 generally resulted in greater increase in average salinity, while Plan B1 showed a lesser effect on average salinity increases. Time average salinity data at the middepth and bottom elevations

(Plate 43) showed that average plan salinity values seaward of mile 3 were generally lower than base conditions, while at the surface depth, plan salinities in this area were slightly higher than base. This indicates a small increase in vertical mixing by the plans. Average salinities for each depth upstream from mile 3 to about mile 18 showed that surface values were generally lower than base, while middepth and bottom values were generally higher. This is an indication of increased stratification. Maximum and minimum salinity values (Plates 44 and 45) followed the same general trend as shown by the average salinity profile. The largest change (increased salinity) resulted from the installation of the degraded jetty plan (B2). The upstream extent of salinity intrusion was unchanged by any of the plans.

48. Time and depth average salinity values obtained along the thalweg of the north channel (Plate 46) followed the same trend as salinity values obtained along the navigation channel center line upstream from mile 6. These data again showed that average salinities (average of surface, middepth, and bottom) resulting from each plan were generally greater than those observed during base conditions. Time average salinities at each depth (Plate 47) showed that each plan resulted in a general increase in average salinity values at middepth and bottom depths and a general decrease at the surface depth. Maximum salinity values (Plate 48) generally demonstrated the greatest increase with Plan B2. Minimum salinity values resulting from each plan were influenced very little or in some locations were slightly lower than base condition values.

49. Jetty B plans. Time and depth average salinity values (Plate 49) along the navigation channel center line for Plans F0 and F1 were generally increased by 1 to 2 ppt throughout the lower 24 miles of the estuary. On the other hand, time average surface salinities for Plan F1 (submerged jetty) between mile 6 to about mile 13 were decreased, generally by less than 0.5 ppt (Plate 50). Plan F0 time average salinity values decreased generally less than 1.0 ppt at the middepth and bottom depth from mile -2 to 2. Maximum and minimum salinities (Plates 51 and 52) along the channel center line generally increased slightly. The most notable increase (2 to 6 ppt) occurred at the bottom depth between miles 6 and 12 during occurrence of minimum salinity concentrations. The maximum extent of salinity intrusion was increased by less than 1 mile.

50. Time and depth average salinity data along the thalweg of the north

channel (Plate 53) reflected the same general trend as was observed along the navigation channel--average salinity values were slightly higher than base (generally less than 2 ppt difference). Plan F1, surface depth, was again the notable exception as time average surface salinity values were lower than base from the entrance up to about mile 13 (Plate 54). Data shown in Plate 54 for Plan F1 indicate a slight tendency toward increased stratification. Maximum and minimum salinity values (Plate 55) were generally higher than base. However, maximum surface salinities for both plans were lower than base up to about mile 13 at this depth. Little change was noted in minimum salinities at the surface and middepth but both plans did result in higher than base salinities (2 to 6 ppt) at the bottom depth.

<u>55-ft channel tests</u>

51. <u>Nonstructural plans.</u> Average, maximum, and minimum salinities resulting from the four nonstructural plans along the channels are shown in Plates 56-62 and 70-76.

52. Time and depth average salinity values along the center line of the navigation channel were increased by each C-series plan (channel deepening only) upstream from about mile 1 (Plate 56), while average salinities seaward of mile 1 were generally lower than those observed with the 48-ft base channel condition. Average salinity values of Plans C1 and C2 when compared with Plan C0 (base condition 55-ft channel) were generally higher; however, exceptions were noted at several stations along the channel. The most notable reduction in average salinities occurred at mile -2, where Plan C0 was 2 to 3 ppt lower than Plans A0 (48-ft channel base condition), C1, and C2. The Plan C0 average data at this station were influenced to a large degree by salinities measured at the surface depth (Plate 57). Surface salinity values at this location were generally very erratic for all tests conducted, and even more so with the 55-ft channels. This station, located about one-third of the distance between the outer end of the jetties and the model headbay, is located in an area that was influenced to some degree by the boundary conditions in the model. In addition, no prototype data were available in the area; therefore model salinity conditions were not verified there.

53. Plan C2 (55 ft deep by 2,000 ft wide) generally resulted in time average surface salinities higher than average surface salinities with the base 55-ft channel (Plan C0) installed (Plate 57), while Plan C1 (transition channel from -55 ft to -48 ft) surface salinities were generally lower than

Plan C0. Average middepth salinities showed that both Plans C1 and C2 were generally higher than Plan C0. Effects on Plan C1 and C2 bottom salinities with respect to Plan C0 were opposite the effects observed at the surface. At the bottom, Plan C1 was higher than Plan C0, while Plan C2 was generally lower. This same trend was observed for maximum and minimum salinity observations (Plates 58 and 59). Maximum and minimum salinity values were generally higher than the base 48-ft channel condition throughout the length of salinity intrusion; however, there was no increase in the length of salinity intrusion for any of the C-series tests.

54. Time and depth average salinities along the thalweg of the north channel (Plates 60 and 61) for the 55-ft channel plans were generally 1 to 2 ppt higher than the 48-ft channel base condition. However, at several stations, time average salinity values at various depths were observed to be lower than base, particularly at the surface. Plan C1 and C2 depth and time average salinities were generally higher than the base 55-ft channel salinities (Plan C0) in the lower reach of the north channel (miles 6 to 10) and about equal or slightly lower in the upper reach of the north channel. Plan C1 average salinities were generally slightly higher than those observed with Plan C2 installed. Maximum and minimum salinity values (Plate 62) followed the same general trend as did average salinity values as bottom and middepth salinity values were higher than base (48-ft channel). Maximum surface salinity values were erratic as both higher and lower values were observed. Plan C1 generally resulted in the greatest changes in maximum salinity values.

55. Data resulting from the 55-ft channel realignment plan (I0) are presented in the same plates as the 60-ft channel test data to conserve space. Effects of the channel realignment plan on average, maximum, and minimum salinity values are shown in Plates 70-76.

56. Effects of the realignment plan on depth and time average salinities (Plate 70) show that the plan resulted in an overall increase of about 1 to 2 ppt from the entrance of the estuary to about mile 18, compared with the 48-ft channel base test. Plate 71, time-averaged salinities at the surface, middepth, and bottom, shows that the greatest increase generally occurred at middepth. A significant increase was indicated at the surface at mile -2 in the entrance; however, as discussed previously, this station is located in the ocean near the model boundary and could possibly be reflecting the boundary conditions rather than the plan. Average bottom depth salinities were about

0.5 ppt higher than base throughout the length of the intrusion zone.

57. Maximum salinity values (Plate 72) were increased at both bottom and middepth throughout the salinity intrusion zone by 1 to 3 ppt and 1 to 6 ppt, respectively. The upstream extent of salinity intrusion was not increased, however. Surface depth maximum salinity values were lower than base from about mile -1 to about mile 5, where they then become 1 to 4 ppt higher than base up to about mile 12. Minimum salinity values at each depth were generally slightly lower than or about equal to base conditions.

58. Depth and time average salinities along the thalweg of the north channel (Plate 74) were increased as a result of the realigned channel. The largest increase of about 3 ppt occurred at mile 14. The mean increase along the north channel was 1 to 2 ppt. Similar to that observed along the navigation channel, the largest increase to salinities occurred at middepth (Plate 75). The increased salinities at the middepth elevation were about 2 to 4 ppt along the entire length of salinity intrusion, while at the surface and bottom elevations, average salinity values showed at most only very small increases above base conditions and were occasionally lower.

59. Maximum and minimum salinities (Plate 76) followed the same trend along the thalweg of the north channel as were observed along the navigation channel. Greatest differences (increased salinity) occurred at the middepth and bottom during periods of maximum salinity. Increased maximum salinity concentrations at middepth and bottom were about 1 to 4 ppt. Surface depth salinities were lower than base from about mile 6 to mile 10, where they then became slightly higher than base conditions. Minimum salinities were generally equal to or slightly lower than base condition values.

60. Plan I0, realignment plan, resulted in an increase in mixing in the estuary, particularly in the middepth zone. This effect on mixing seemed to have resulted in higher salinity concentrations in the middle portion of the salinity intrusion zone. Salinity intrusion farther upstream could result; however, the model results showed the distance would not be significant.

61. Structural plans. The effects of the three structural 55-ft channel plans on average, maximum, and minimum salinity values are shown in Plates 63-70.

62. The overall effect of the three plans, when compared with the base condition 55-ft channel, were very similar (Plate 63). Time and depth average salinities between miles -2 and 0 were increased (1 to 2 ppt); remained about

the same as base from mile 0 to about mile 2; and were lower (1 to 2 ppt) than base from about mile 2 to about mile 7, at which point they became higher (1 to 4 ppt) than base upstream to about mile 18. Plan G0 (full height jetty B plan) effects were generally greater than the other two plans where salinity increases were evident, and less where decreased salinity effects were evident. Plan G1 (submerged jetty, 300 ft shorter than Plan G0) effects were generally less than the other two plans where salinities were greater than base, and greater where salinities were less than base conditions. The maximum decreases in average salinities occurred at about mile 4 (generally about 1 to 2 ppt) while the maximum increases occurred at about mile 14 (generally about 2 to 3 ppt).

63. The decreases in salinities between miles 2 to 6 (Plate 64) were influenced primarily by the large decreases observed at the surface depth. Middepth and bottom salinities generally showed that each plan resulted in very little change or small increases in this area. The large increases in average salinity values appearing between mile 7 to the upper end of the intrusion zone were influenced primarily by the large increases at the middepth and bottom. These data (Plates 63 and 64) show that either plan results in an apparent increase in vertical mixing in the entrance and an increase in salinity intrusion of 1 to 2 miles.

64. Maximum and minimum salinities (Plates 65 and 66) followed the same general trend as shown by the time and depth average data (Plate 63). Maximum salinity values were influenced the greater amount at the surface, while minimum salinities were affected most at the bottom. Maximum surface salinities were decreased as much as 7 ppt (Plan G2) at mile 4, and increased as much as 11 ppt (Plan G1) at mile 10. The greatest changes were 13 and 14 ppt and occurred at about mile 14 during the occurrence of minimum salinity with Plans G0 and G2, respectively. Maximum bottom and minimum surface salinity values were the least affected by either plan. Either plan would result in a small increase in vertical mixing in the lower estuary (miles -2 to 6). Salinity intrusion would be increased slightly, with Plan G0 resulting in the greatest increase.

65. Salinity data along the thalweg of the north channel (Plate 67) showed that time and depth average salinities for Plan G0 followed the same general trend as was observed along the center line of the navigation channel upstream of mile 6--salinities upstream of this point to about mile 16 were

higher than those observed for base conditions. However, Plans G1 and G2 showed a reverse effect in the north channel as was observed along the navigation channel upstream from about mile 10 to about mile 18. Average salinities in that reach of the north channel with Plans G1 and G2 were decreased from what was observed during base conditions, generally about 1 ppt or less. Plan G0 data at surface, middepth, and bottom (Plate 68) showed a general increase in time average salinities at each depth, with small exceptions at mile 8, surface depth, and at miles 6, 12, 16, and 18 at the bottom. The general trend observed in the north channel time average salinities at surface, middepth, and bottom elevations was similar to that observed along the navigation channel, but Plans G1 and G2 seemed to result in reduced salinity effect farther upstream than was observed in the navigation channel. Largest effects from each plan occurred generally at about mile 8. Largest reduction in average salinity occurred at the surface at this point, while largest increases occurred at the bottom depth at this location. From data shown in Plate 68, each plan resulted in a general decrease in vertical mixing from about mile 7 to about mile 10. The upstream extent of salinity intrusion in the north channel would be reduced about 2 miles by each of these three plans.

66. Maximum and minimum salinity values followed the same general pattern as was observed for average salinity. The greatest increase (about 6 ppt) in surface maximum salinities occurred at about mile 12 with Plan G0. The greatest decrease (about 3 ppt) at the surface occurred at mile 8 with Plan G1 installed. The greatest effect, a decrease in maximum salinity values at the bottom, occurred at about mile 18. Here all plans showed maximum values almost 7 ppt lower than base values. Maximum values at the middepth reflected only small variations from base condition values. Minimum salinity values at the surface and middepth were generally slightly higher than base. Bottom depth minimum values were likewise generally higher with all three plans but the magnitude of effects was greater than that observed at the surface and middepth.

<u>60-ft channel tests</u>

67. The effects of the two 60-ft channel plans on average, maximum, and minimum salinity values are shown in Plates 70-76. Each plan, compared with the base 48-ft channel, resulted in increased time and depth average salinity values along the channel center line as shown in Plate 70. Plan H0 (base condition 60-ft channel) generally resulted in a greater increase to average

salinities than did Plan H1 (60-ft channel combined with submerged jetty B and authorized south jetty). Average salinity values along the channel center line with Plan H0 installed reflected increases from 1 to about 4 ppt, while Plan H1 increases were on the order of 1 to 2 ppt. The largest increases with each plan occurred between miles 10 and 16.

68. The overall increase in time and depth average salinity values (Plate 70) was the result primarily of the large increase occurring at mid-depth and bottom (Plate 71). Time average salinity values at the surface depth were somewhat erratic as both decreased and increased average salinity values were evident at stations along the navigation channel.

69. Maximum and minimum salinity values (Plates 72 and 73) showed the greatest changes (generally increased salinity values) at middepth and bottom for both plans. Effects of the two plans were very similar during the occurrence of maximum salinity; however, effects during the occurrence of minimum salinity (low water) were quite different, particularly at the bottom. Plan H0 minimum salinity values at the bottom were generally 4 to 10 ppt higher than base, while Plan H1 minimum salinity values were lower than base conditions from mile -2 to about mile 6, where they became equal to or slightly higher than base conditions.

70. From the data shown in Plates 70-73, either of the 60-ft channel plans would result in slightly increased salinity intrusion along the navigation channel. Plan H0 would also result in a slightly more stratified salinity condition along the navigation channel.

71. The effects of Plans H0 and H1 on time and depth average salinities along the thalweg of the north channel were very similar to their effects at stations located along the navigation channel upstream from mile 6 (Plate 74). Each plan resulted in an overall increase in average salinity concentrations of about 1 to 2 ppt. These increases were, as observed along the navigation channel, influenced to a great degree by the rather large increase observed at the middepth and bottom elevation (Plate 75). Greater increases in time average salinity occurred with Plan H0 than with Plan H1 at the middepth and bottom, but salinities for Plan H0 were less than for Plan H1 at the surface. This same trend was observed at stations along the navigation channel. Also similar to the trend observed along the navigation channel, greatest effects in the north channel occurred between miles 10 and 16. Plan H0 again resulted in the greatest increases except at the surface depth. Average surface

salinities for Plan HO were less than base condition concentrations from about miles 6 to 10 and greater than base from about miles 10 to 18. Plan H1 average surface salinities were generally about the same as, or slightly higher than, base conditions. Average salinities at middepth and bottom with Plan HO were generally about 2 to 4 ppt higher than base up to about mile 18, where they became about equal to base condition values. Plan H1 average salinities at middepth and bottom were generally about 1 to 3 ppt higher than those observed for base conditions. Stratification was increased somewhat by Plan HO.

72. Maximum and minimum salinity profiles (Plate 76) followed the same general trend as that observed for the average salinity data in the north channel. Differences in maximum salinity concentrations were generally on the same order of magnitude as those observed for average salinity data. The largest increase in salinities was observed with Plan HO at the bottom depth, during the occurrence of minimum salinities, where minimum salinity values were generally about 4 to 6 ppt higher than those of the base or Plan H1. The extent of salinity intrusion was reduced by about a mile by Plan HO but unchanged by Plan H1.

Shoaling Results (Hybrid Model)

73. Results of hybrid shoaling tests are presented as dredging volumes distribution and as shoaling pattern maps for the entrance. Table 3 summarizes the dredging volume requirements of all the plans, showing the volume distribution by river mile, the total dredged volume, and the dredging index for each plan. The dredging index is the total dredged volume for a plan divided by the total dredged volume for the base test. Figure 4 shows the elements making up the navigation channel in the area of interest. The dredged volumes shown in Table 3 are the sum of volumes in the cross-channel row of elements located at the designated river mile. The channel element lengths vary somewhat; therefore volumetric comparisons between the element row sums may not be directly proportional to depth of deposition. Dredged volumes are the quantities of material accumulating within the channel prism lines above a plane that is 2 ft deeper (overdepth) than the nominal, or design, depth. Thus the volumes reflect perfect maintenance of the design channel with 2 ft of overdepth.

74. Tables 4-20 show each plan's dredging volume breakdown by channel

segment as well as by river mile. The channel is divided into three rows of elements, with the northern row (elements 76-83, see Figure 4) covering the left quarter, the center row (elements 59-66) covering the center half, and the southern row (elements 42-49) covering the right quarter of the channel. Prototype dredging volume distribution across the channel was not available; therefore the model was not verified to reproduce this effect accurately. The data have been presented because of their potential usefulness but should be used with care.

75. Shoaling patterns for the entrance area under base (existing conditions, Plan A0) are shown in Plates 77 and 78. Because of scanty field data, only the navigation channel and a narrow band on either side of it were verified to reproduce prototype scour and fill patterns. Outside the verified area the results should be viewed with some caution and used primarily to compare the plans. The shoaling verification is described in detail in McAnally et al. (in preparation).

48-ft channel tests

76. Effects of the 48-ft channel plans are given in Tables 3-11 and Plates 77-87.

77. North jetty plans. Tables 3-6 and Plates 77-80 show that varying the length of the north jetty had very little effect on the total dredged volume. Increasing jetty length by more than 1,300 ft (Plan A1) decreased the total volume by only 2 percent, principally between miles 0.5 and 1.5. This agrees with the previous physical model study (Herrmann and Simmons 1966) which predicted that restoration of the jetty's full length would reduce channel shoaling by only about 5 percent. Permitting the jetty to degrade somewhat further (Plan A2) did not change required dredging from that for Plan A0.

78. Examination of the shoaling pattern maps (Plates 78 and 79) shows that extending the north jetty caused the zone of deposition on the seaward end of the channel bend to be reduced somewhat from the base, and the pattern immediately around the jetty to also change. Differences between the base and the degraded jetty plan (Plate 80) were minor.

79. South jetty plans. Plates 81-84 illustrate the shoaling effects of Plans B1, B2, and B3. None of the three plans effected a reduction in dredged volumes, with the smallest increase, 10 percent, occurring for the shortened jetty (Plan B2). In the previous physical model study (Herrmann and Simmons 1966), a plan (Plan 2) similar to Plan B2 showed a potential 18 percent

reduction in channel shoaling. Plans B1 and B3, jetty lengthening plans, showed dredged volume increases of 50 percent and 20 percent, respectively. Most of the increase occurred between miles 0.5 and 1.5. These results suggest that the jetty length for minimum dredging lies between that of Plans B1 and B3.

80. The shoaling pattern plots (Plates 82-84) for the B series plans do not reveal any dramatic changes in pattern from the base condition (Plate 78). They do show a slight expansion of the deposition zone at about mile 1.5 for Plans B1 and B3, which is consistent with the dredged volume increase observed in that area.

81. Jetty B plans. Both of the tested jetty B plans (Plate 85) caused a substantial increase in dredged volume over base conditions. The full height jetty (Plan F0) resulted in significantly larger volumes in the area from mile 0 to -1 even though it reduced volumes somewhat in the immediate area of the jetty. Submerging the jetty (Plan F1) resulted in a less harmful effect in the outer portion of the channel but increased shoaling upstream near the jetty. It can be hypothesized that submerging the jetty caused less of an energy loss due to the sudden expansion of flow downstream of the jetty, but it is not obvious why shoaling would increase off the tip of the jetty as occurred for Plan F1 at mile 1.8.

82. In an earlier, physical model study of jetty B, Herrmann (1974) found that a longer jetty B located upstream of the location tested here would reduce shoaling by about 30 percent. All of the decrease was located landward of mile 1 and shoaling did increase at mile 0, as occurred in the tests reported here.

83. It is interesting to note that the shoaling pattern maps (Plates 86 and 87) suggest that both jetty B plans pushed the depositional zone of Clatsop Spit between the channel and south jetty back toward the south jetty. This, plus the earlier tests showing that a jetty B could reduce shoaling somewhat, suggests that a structure might help the channel shoaling problem at mile 0, if the best alignment and length could be found.

55-ft channel tests

84. Results of shoaling tests for a 55-ft-deep entrance channel are given in Tables 3 and 12-18 and Plates 88-97.

85. Nonstructural plans. Results of channel deepening without structural modifications showed substantial increases in dredged volumes for the

55-ft channel over the 48-ft channel. Plan C0, the simple deepening plan, doubled the dredged volume, with the biggest increases coming in the zone between miles 0.5 and 1.5. Reducing channel depth upstream of mile 1 (Plan C1) reduced the volume increase from that point upstream but increased it in the seaward direction. It appears that extending the depth breakpoint seaward to about mile 0.5 would help substantially. The narrower channel of Plan C2 resulted, as expected, in a substantially lower dredged volume than Plan C0. It still represents a 30 percent increase in volume over the base test, but nearly all of the increase is in the landward part of the channel, upstream from mile 0.5.

86. Plates 89-91 illustrate that the area of heaviest deposition expands upstream for all the C-series plans. Plan C2 does not significantly alter the entrance geometry and succeeds in keeping the dredged volume down only because so much of the dredged volume occurs on the south side of the full-width channel (compare Tables 12 and 14).

87. Results of Plan I0 (realigned channel) are compared with the base and Plan C0 in Plate 92 and the Plan I0 shoaling pattern map is Plate 93. Plan I0 resulted in an even larger increase in dredged volume (160 percent) over base conditions than did Plan C0. The additional increase over the base occurred at every row of elements; reasons for this result are not known. Examination of the shoaling pattern map (Plate 93) shows some variation in deposition patterns, notably a large area of Plan I0 deposition in the channel at about mile 0.5 and between the channel and south jetty. Most of the increase compared with Plan C0 occurred in the center half of the channel (compare Tables 12 and 15).

88. Structural plans. Results of the G-series plans, involving various structural modifications to the 55-ft channel plan, are shown in Tables 3 and 16-18 and Plates 94-97. Plans G0 and G2 resulted in modest reductions in total dredged volumes from the base 55-ft channel condition (Plan C0); but Plan G1 increased them. Plans G0 and G2 significantly reduced volumes upstream of mile 1. Comparison of shoaling patterns (Plates 95-97) with those of Plan C0 (Plate 89) shows that the jetty B substantially reduces the channel shoal upstream of about mile 1.2 in Plan G0, and in Plan G2 to a lesser extent. Both plans show a retreat of the upstream end of the Clatsop Spit shoal. In contrast, Plan G1, with the authorized south jetty, shows renewed channel shoaling up to about mile 1.8 (actually somewhat greater than for Plan C0).

Plan G1, like the other jetty B plans, results in a reduction of the Clatsop Spit shoal.

60-ft channel tests.

89. Results for the H-series of tests are shown in Tables 3, 19, and 20 and Plates 98-100. The 60-ft-deep channel is seen to dramatically increase dredged volumes over the 48-ft channel, with shoaling indices of 2.8 and 3.0 for Plans H0 and H1, respectively. Volumes increased at every channel mile, but the largest absolute increases occurred upstream of mile 0.5.

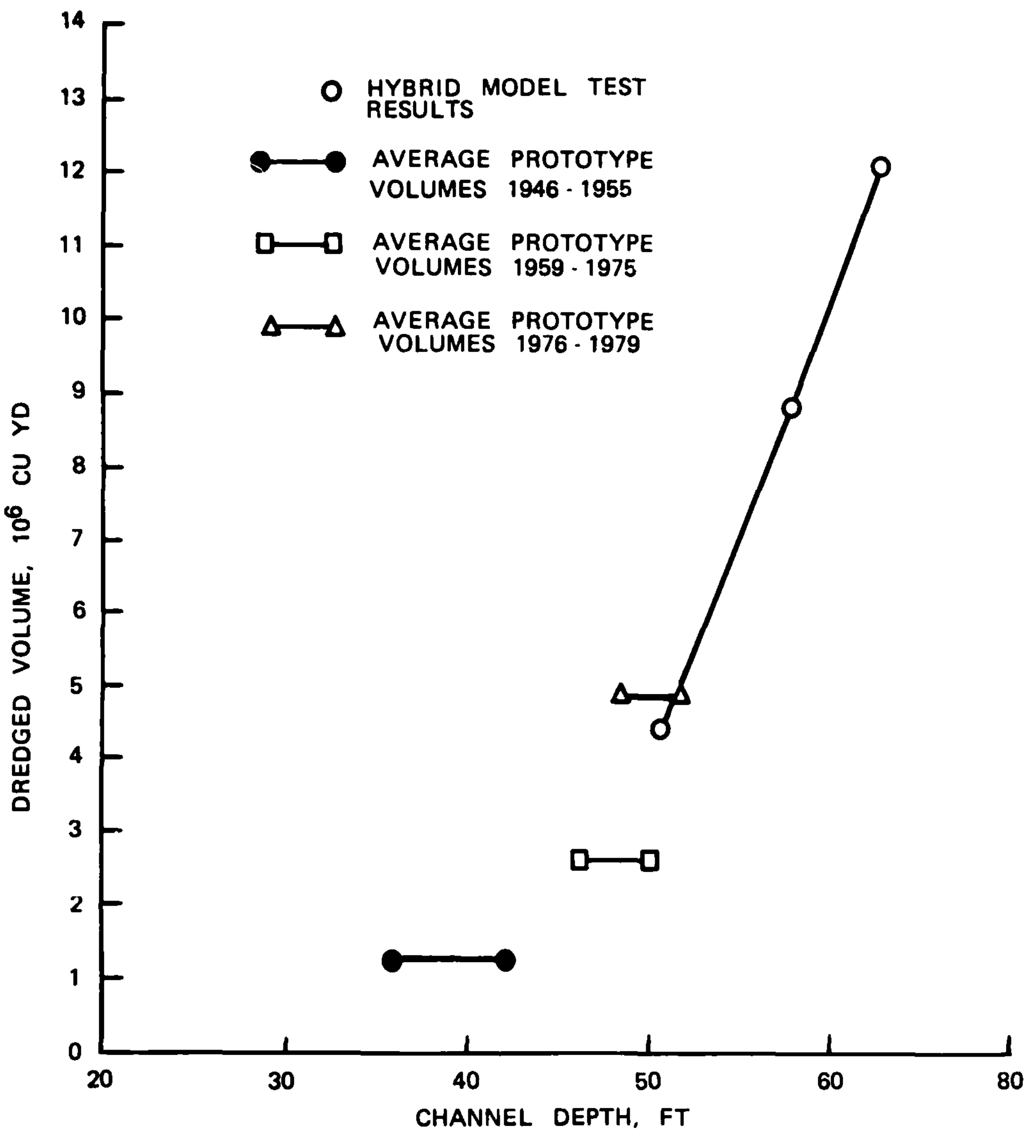
90. Shoaling patterns (Plates 99 and 100) are quite similar to that of Plan C0 (55-ft channel). The most notable increase in deposition occurred adjacent to Clatsop Spit.

91. Addition of a submerged jetty B (Plan H1) caused a slight increase in channel dredging for the 60-ft channel, a consequence consistent with Plan F1 results (compared with the 48-ft channel base test), although at a magnitude of 12,000,000 cu yd the absolute results are probably not sufficiently reliable to distinguish relatively small differences in volume.

Effect of channel depth on dredging

92. Plate 101 illustrates the effect of progressive channel deepening on predicted dredging volumes. Increasing the depth from 48 to 55 ft doubled the total dredged volume from 4.4 to 8.7 mcy, and increasing the depth to 60 ft raised the volume to 12 mcy. The peak dredging volume shifted upstream from about mile 0.6 for the base to mile 1.2 for the 55- and 60-ft channels. Similarly, relative increases in volume were larger in the upstream direction (excluding mile -1.8, where negligible dredging occurred for the 48-ft channel). This trend is consistent with the notion that salinity intrusion, and thus the zone of increased shoaling, will move upstream as a channel is deepened.

93. Figure 5 compares the variations in total dredged volume from the model tests with prototype experience. The model results, for actual channel depths (including overdepth) from 50 to 62 ft, fall almost on a straight line. The prototype volumes are average dredged volumes over three periods in which different channel depths prevailed. The range of channel depths indicates the range of controlling depths during most of each period. The ranges for the latter two prototype periods are consistent with the curve given by the model results. Since the prototype volumes do not reflect perfect maintenance of the design channel, the degree of correspondence is quite good in the range of



NOTE: PROTOTYPE DATA FROM ANNUAL REPORTS OF THE CHIEF OF ENGINEERS, 1946 - 1979 AND CHANNEL CONDITION SURVEYS 1972 - 1979

Figure 5. Variation of dredged volumes with channel depth

46 to 51 ft. The shallower channel depth volumes for 1946-1955 do not fall on an extrapolated model results line; but they would not be expected to since the equilibrium channel depth (zero maintenance) was on the order of 20 ft (Office, Chief of Engineers 1910) giving the lower portion of the curve a non-linear shape.

94. It is probable that there exists an annual maximum dredging volume which could not be exceeded, no matter how deep the channel was dredged.

These model results indicate that that volume is at least greater than 12 mcy. It has been suggested that the maximum possible shoaling volume is limited by supply to 4 or 5 mcy/year, based on an analysis of dredged volumes and bed changes from 1976 to 1980. This estimate is believed to be low.

95. The entrance accumulates sand from upstream supply and entrapment of littoral drift. Estimates of the quantity of material in transport are highly approximate but give some indication of the supply of material available for deposition. Hickson (1961) estimated that the river's suspended load passing through the entrance was 8 mcy/year. Assuming that 10 percent or less of this material is sand (Hubbell, Glenn, and Stevens 1971) and adding that to Hickson's estimate of 3.5 mcy/year bed load yields a total bed material load of about 4.0 mcy/year from upstream. This agrees with Hickson's estimate of 4 mcy/year accumulating on the outer bar.

96. Lockett (1963) analyzed hydrographic surveys of the areas north and south of the entrance for 1877 and 1926, the period in which the jetties were built. He found that during the 50 years, accretion to the north of the mouth averaged 3.7 mcy/year while erosion to the south averaged 7.5 mcy/year. During the subsequent 32 years, accretion and erosion in each of those respective areas averaged about 4.1 mcy/year. After an initial deepening following each episode of jetty building, progressive infilling of the entrance channel continued during these periods. This suggests a net littoral transport of at least 4 to 8 mcy/year at the mouth of the Columbia. The gross amount (total northward movement plus total southward movement) moving past the entrance after completion of infilling behind the jetties would be substantially more than this.

97. Taking 4 mcy/year as a minimum net littoral transport rate and adding it to Hickson's estimated 4 mcy/year upstream sand supply results in a minimum total supply of about 8 mcy/year. If these estimates are correct, the maximum possible shoaling rate must be in excess of 8 mcy/year. Since these are net rates of transport, they are definitely not an absolute upper limit on deposition rate. For example, if the navigation channel were a perfect sediment trap, all of the back and forth moving material that strayed into the channel during a tidal cycle would deposit and the rate could be half an order of magnitude greater.

98. From these analyses and the 12 mcy/year model results for the 60-ft channel, it is probable that the maximum possible shoaling rate is in excess

of 12 mcy/year. Note that this is not the same as concluding that the 12 mcy/year shoaling rate is correct; it merely establishes that such a volume is within reason. Model results may be too high, since the models become progressively less reliable as conditions (e.g. channel depths) become less like those under which the model was verified.

PART IV: CONCLUSIONS

99. Sixteen plans and the base conditions of the mouth of the Columbia River were tested with the Columbia Hybrid Modeling System. Seven of the plans consisted of attempts to reduce shoaling in the existing 48-ft-deep navigation channel. The rest of the plans consisted of 55- and 60-ft-deep entrance channels and structure plans. Data were collected to define plan effects on tidal elevations, current velocities, bottom flow predominance, salinities, shoaling patterns, and maintenance dredging volumes.

100. Tidal elevations were affected to only a slight degree, except for localized effects near the plan structures. The most significant change was small increase in mean tide levels at sta 54 and 849 in the 60-ft channel tests.

101. Effects of the plans on current velocities were subtle--current speed rarely changed by more than 1 fps--and changes were primarily reflected in the bottom flow predominances. The full height jetty B increased ebb predominance on the south side of the channel and decreased it on the north side. Channel deepening caused a decrease in ebb predominance on the south side.

102. Plans for the 48-ft-deep channel had relatively minor effects on salinity intrusion. Mixing within the entrance was altered somewhat, but most changes were within 2 ppt and were limited to the area downstream of mile 12. The 55- and 60-ft channel plans increased salinities 1 to 6 ppt over those of the base test, and the changes occurred up to about mile 18.

103. Of the several plans tested for the 48-ft channel, only lengthening the north jetty reduced dredging volumes below base test values. Extending or shortening the south jetty or construction of either of the two jetty B plans increased dredged volumes. The 48-ft channel test results suggest that (a) between the authorized and degraded south jetty lengths there is a length near present conditions that minimizes maintenance dredging and (b) there is probably a jetty B location and design that will reduce dredging quantities. These observations are consistent with previous, fixed-bed model results.

104. Deepening the channel to 55 ft doubled dredged volumes from the base test; narrowing the maintained channel, tapering the depth back to 48 ft, and two structural modifications reduced the 55-ft channel dredging requirements somewhat. The structural modifications reduced shoaling mainly on the upstream end of the deposition zone.

105. Deepening the channel to 60 ft almost tripled the dredged volume from the base test. The only structural modification tested was not effective in reducing shoaling for the 60-ft channel.

106. The relationship between channel depth and required dredging was nearly linear in these tests. On the lower end of the depth scale, those depths for which the models were verified, the agreement with prototype trends is good. The magnitude of the dredging increase for the 60-ft-deep channel is so large that model verification may have been strained. If so, the actual increase might be considerably different. However, analysis of other data shows that the 60-ft channel tests result of 12 mcy/year does not exceed the probable total sediment supply to the entrance.

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Table 1

Entrance Channel Plan Conditions

Plan	Channel	Structures
A0	48 × 2,640 ft	Existing
A1		Existing plus authorized north jetty length
A2		Existing plus shortened north jetty
B1		Existing plus authorized south jetty length
B2		Existing plus shortened south jetty
B3		Existing plus partially rehabilitated south jetty
F0		Existing plus full height, 4,106-ft-long jetty B
F1		Existing plus submerged, 4,106-ft-long jetty B
C0	55 × 2,640 ft	Existing
C1	55 × 2,640 ft from mile 1 to mile -2 48 × 2,640 ft from mile 1 upstream	Existing
C2	55 × 2,000 ft	Existing
I0	Realigned 55 × 2,640 ft	Existing
G0	55 × 2,640 ft	Existing plus full height, 4,106-ft-long jetty B
G1	55 × 2,640 ft	Existing plus submerged, 3,806-ft-long jetty B and groin near end of north jetty
G2	55 × 2,640 ft	Existing plus submerged, 3,806-ft-long jetty B, groin near end of north jetty, and authorized south jetty
H0	60 × 2,640 ft	Existing
H1	60 × 2,640 ft	Existing plus submerged, 4,106-ft-long jetty B and authorized south jetty

Table 2

Bottom Flow Predominance

Plan	Percent Total Flow Downstream	
	Sta 127	Sta 286
Base (A0)	49	47
A1	*	41
A2	*	47
B1	47	47
B2	51	51
B3	47	53
F0	57	33
F1	50	40
C0	44	44
C1	48	40
C2	52	35
G0	56	31
G1	47	43
G2	49	47
I0	52	43
H0	38	46
H1	41	48

* Not measured.

Table 3

Computed Annual Dredging Volumes, Millions of Cubic Yards

River Mile	Plan																
	A0	A1	A2	B1	B2	B3	F0	F1	C0	C1	C2	I0	G0	G1	G2	H0	H1
1.9	0.29	0.32	0.28	0.57	0.32	0.32	0.08	1.04	1.01	0.74	0.72	1.37	0.24	1.13	0.49	1.42	1.34
1.2	0.91	0.77	0.92	1.63	1.10	1.12	0.66	1.30	2.31	1.29	1.58	2.74	1.41	2.47	1.49	3.25	3.38
0.6	1.10	0.87	1.15	1.74	1.28	1.42	1.49	1.30	2.09	2.42	1.28	2.84	2.24	2.41	1.99	2.94	3.27
0.0	0.61	0.56	0.59	0.73	0.67	0.78	1.29	0.66	0.96	1.10	0.57	1.22	1.26	1.21	0.96	1.25	1.38
-0.8	0.99	0.95	0.95	1.18	1.08	1.13	1.68	0.96	1.27	1.29	0.84	1.46	1.76	1.79	1.54	1.83	2.04
-1.3	0.39	0.41	0.36	0.45	0.38	0.42	0.61	0.24	0.59	0.65	0.44	0.81	0.82	0.90	0.76	0.88	1.00
-1.8	0.01	0.30	0.01	0.07	0.03	0.03	0.01	0.00	0.35	0.32	0.25	0.50	0.33	0.63	0.40	0.44	0.47
Total*	4.3	4.2	4.3	6.4	4.9	5.2	5.8	5.6	8.6	7.8	5.7	11	8.1	10	7.6	12	13
Dredging index	1.0	1.0	1.0	1.5	1.1	1.2	1.3	1.3	2.0	1.8	1.3	2.6	1.9	2.3	1.8	2.8	3.0

* Rounded to two significant figures.

Table 4

Plan A0 Dredging Volumes, Millions of Cubic Yards

River Mile		North 1/4		Center 1/2		South 1/4
1.9		0.16		0.07		0.06
1.2		0.41		0.32		0.18
0.6		0.32		0.44		0.34
0.0		0.13		0.29		0.19
-0.8		0.21		0.50		0.28
-1.3		0.09		0.19		0.11
-1.8		0.01		0.00		0.00
	Total*	1.3	+	1.8	+	1.2

Table 5

Plan A1 Dredging Volumes, Millions of Cubic Yards

River Mile		North 1/4		Center 1/2		South 1/4
1.9		0.16		0.09		0.07
1.2		0.31		0.27		0.19
0.6		0.19		0.36		0.32
0.0		0.12		0.27		0.17
-0.8		0.16		0.48		0.31
-1.3		0.09		0.19		0.13
-1.8		0.28		0.01		0.01
	Total*	1.3	+	1.7	+	1.2

Table 6

Plan A2 Dredging Volumes, Millions of Cubic Yards

River Mile		North 1/4		Center 1/2		South 1/4
1.9		0.15		0.08		0.05
1.2		0.39		0.35		0.18
0.6		0.32		0.48		0.35
0.0		0.12		0.28		0.19
-0.8		0.21		0.48		0.26
-1.3		0.08		0.17		0.11
-1.8		0.01		--		0.00
	Total*	1.3	+	1.8	+	1.1

* Total in each table rounded to two significant figures.

Table 7

Plan B1 Dredging Volumes, Millions of Cubic Yards

River Mile	North 1/4		Center 1/2		South 1/4
1.9	0.27		0.18		0.12
1.2	0.64		0.65		0.34
0.6	0.51		0.74		0.49
0.0	0.19		0.35		0.19
-0.8	0.25		0.59		0.34
-1.3	0.10		0.21		0.14
-1.8	0.04		0.02		0.01
Total*	2.0	+	2.7	+	1.6

Table 8

Plan B2 Dredging Volumes, Millions of Cubic Yards

River Mile	North 1/4		Center 1/2		South 1/4
1.9	0.18		0.10		0.04
1.2	0.50		0.44		0.16
0.6	0.41		0.55		0.32
0.0	0.16		0.32		0.19
-0.8	0.22		0.54		0.32
-1.3	0.08		0.18		0.12
-1.8	0.02		0.01		0.00
Total*	1.6	+	2.1	+	1.2

Table 9

Plan B3 Dredging Volumes, Millions of Cubic Yards

River Mile	North 1/4		Center 1/2		South 1/4
1.9	0.14		0.09		0.09
1.2	0.41		0.42		0.29
0.6	0.35		0.61		0.46
0.0	0.17		0.39		0.22
-0.8	0.25		0.56		0.32
-1.3	0.11		0.19		0.12
-1.8	0.02		0.01		0.00
Total*	1.4	+	2.3	+	1.5

* Total in each table rounded to two significant figures.

Table 10

Plan F0 Dredging Volumes, Millions of Cubic Yards

River Mile	North 1/4	Center 1/2	South 1/4
1.9	0.08	0.00	0.00
1.2	0.42	0.18	0.06
0.6	0.44	0.62	0.43
0.0	0.19	0.64	0.46
-0.8	0.46	0.83	0.39
-1.3	0.19	0.29	0.13
-1.8	0.01	--	0.00
Total*	1.8 +	2.6 +	1.5

Table 11

Plan F1 Dredging Volumes, Millions of Cubic Yards

River Mile	North 1/4	Center 1/2	South 1/4
1.9	0.65	0.39	--
1.2	0.72	0.49	0.09
0.6	0.58	0.51	0.21
0.0	0.18	0.31	0.17
-0.8	0.21	0.47	0.28
-1.3	0.04	0.11	0.09
-1.8	0.00	--	0.00
Total*	2.4	2.3	0.8

Table 12

Plan C0 Dredging Volumes, Millions of Cubic Yards

River Mile	North 1/4	Center 1/2	South 1/4
1.9	0.39	0.37	0.25
1.2	0.75	1.00	0.56
0.6	0.52	0.94	0.63
0.0	0.26	0.46	0.24
-0.8	0.33	0.61	0.33
-1.3	0.16	0.28	0.15
-1.8	0.12	0.16	0.07
Total*	2.5 +	3.8 +	2.2

* Total in each table rounded to two significant figures.

Table 13

Plan C1 Dredging Volumes, Millions of Cubic Yards

River Mile	North 1/4		Center 1/2		South 1/4
1.9	0.28		0.27		0.19
1.2	0.46		0.52		0.31
0.6	0.62		1.05		0.75
0.0	0.25		0.53		0.32
-0.8	0.35		0.62		0.32
-1.3	0.19		0.31		0.15
-1.8	0.11		0.14		0.07
Total*	2.3	+	3.4	+	2.1

Table 14

Plan C2 Dredging Volumes, Millions of Cubic Yards

River Mile	North 1/4		Center 1/2	South 1/4
1.9	0.39		0.33	Not dredged
1.2	0.69		0.89	
0.6	0.51		0.77	
0.0	0.19		0.38	
-0.8	0.28		0.56	
-1.3	0.16		0.28	
-1.8	0.11		0.14	
Total*	2.3	+	3.4	

Table 15

Plan I0 Dredging Volumes, Millions of Cubic Yards

River Mile	North 1/4		Center 1/2		South 1/4
1.9	0.56		0.49		0.32
1.2	0.92		1.14		0.68
0.6	0.71		1.22		0.91
0.0	0.29		0.59		0.34
-0.8	0.39		0.72		0.35
-1.3	0.25		0.39		0.17
-1.8	0.19		0.23		0.08
Total*	3.3	+	4.8	+	2.8

* Total in each table rounded to two significant figures.

Table 16

Plan G0 Dredging Volumes, Millions of Cubic Yards

River Mile	North 1/4		Center 1/2		South 1/4
1.9	0.24		--		0.00
1.2	0.61		0.51		0.29
0.6	0.58		0.95		0.71
0.0	0.28		0.57		0.41
-0.8	0.48		0.86		0.42
-1.3	0.25		0.39		0.18
-1.8	0.11		0.15		0.07
Total*	2.6	+	3.4	+	2.1

Table 17

Plan G1 Dredging Volumes, Millions of Cubic Yards

River Mile	North 1/4		Center 1/2		South 1/4
1.9	0.47		0.38		0.28
1.2	0.87		0.98		0.62
0.6	0.61		1.01		0.79
0.0	0.33		0.55		0.33
-0.8	0.41		0.84		0.54
-1.3	0.24		0.41		0.25
-1.8	0.21		0.29		0.13
Total*	3.1	+	4.5	+	2.9

Table 18

Plan G2 Dredging Volumes, Millions of Cubic Yards

River Mile	North 1/4		Center 1/2		South 1/4
1.9	0.31		0.05		0.13
1.2	0.55		0.51		0.43
0.6	0.48		0.86		0.65
0.0	0.24		0.46		0.26
-0.8	0.37		0.74		0.43
-1.3	0.21		0.36		0.19
-1.8	0.14		0.18		0.08
Total*	2.3	+	3.2	+	2.2

* Total in each table rounded to two significant figures.

Table 19

Plan H0 Dredging Volumes, Millions of Cubic Yards

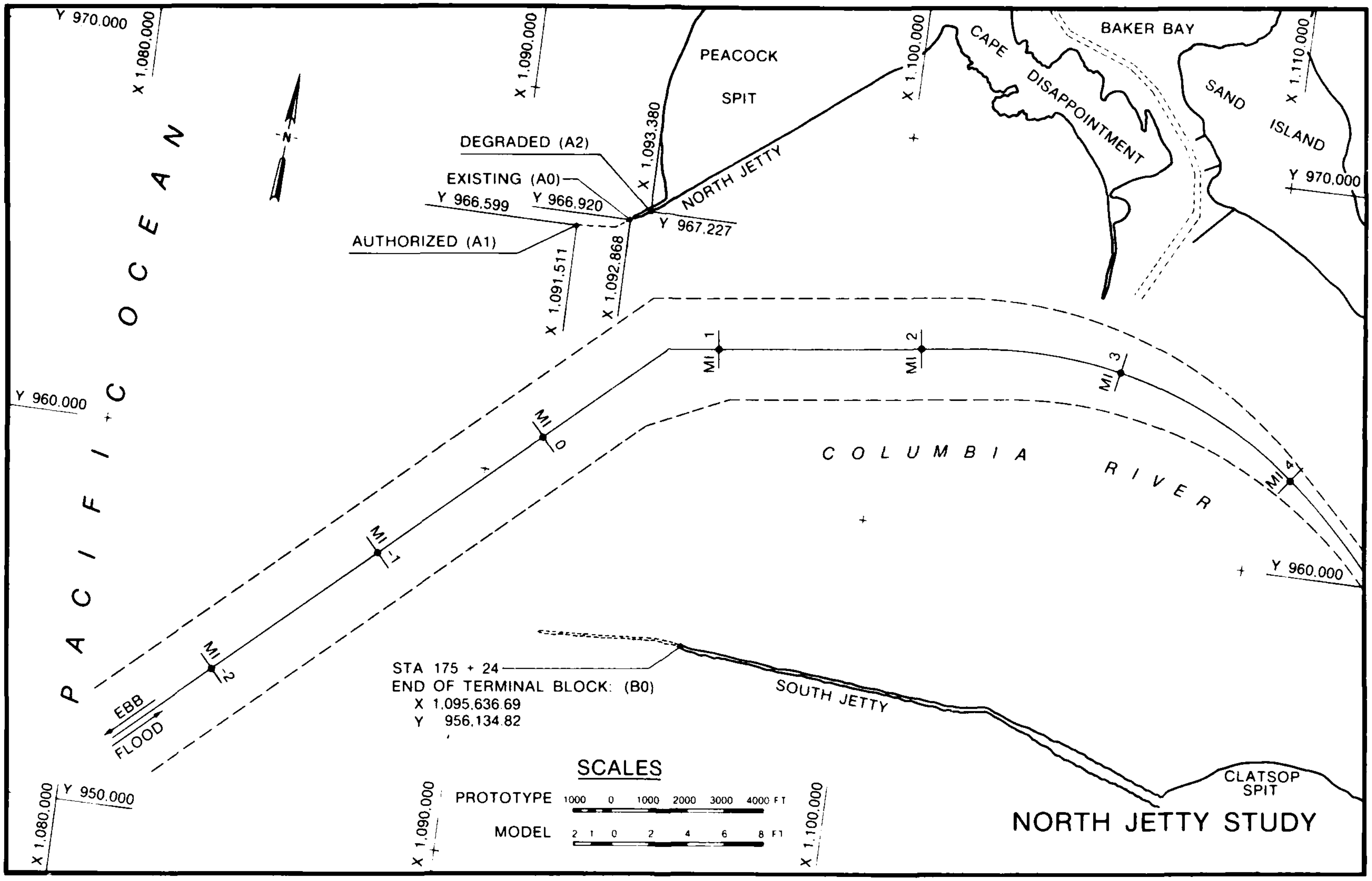
River Mile	North 1/4		Center 1/2		South 1/4
1.9	0.61		0.46		0.35
1.2	1.08		1.38		0.79
0.6	0.73		1.29		0.92
0.0	0.29		0.58		0.38
-0.8	0.49		0.89		0.45
-1.3	0.27		0.42		0.19
-1.8	0.16		0.19		0.09
Total*	3.6	+	5.2	+	3.2

Table 20

Plan H1 Dredging Volumes, Millions of Cubic Yards

River Mile	North 1/4	Center 1/2	South 1/4
1.9	0.62	0.37	0.35
1.2	1.15	1.39	0.84
0.6	0.83	1.44	1.00
0.0	0.32	0.65	0.41
-0.8	0.56	0.99	0.49
-1.3	0.31	0.47	0.22
-1.8	0.17	0.21	0.09
Total*	4.0	5.5	3.4

* Total in each table rounded to two significant figures.


NORTH JETTY STUDY
PACIFIC OCEAN
COLUMBIA RIVER
PEACOCK SPIT
CAPE DISAPPOINTMENT
BAKER BAY
SAND ISLAND
CLATSOP SPIT
NORTH JETTY
SOUTH JETTY
N
DEGRADED (A2)
EXISTING (A0)
AUTHORIZED (A1)
Y 966.599
Y 966.920
Y 967.227
X 1.093.380
X 1.092.868
X 1.091.511
STA 175 + 24
END OF TERMINAL BLOCK: (B0)
X 1.095.636.69
Y 956.134.82
EBB
FLOOD
MI -2
MI -1
MI 0
MI 1
MI 2
MI 3
MI 4
Y 970.000
Y 960.000
Y 950.000
X 1.080.000
X 1.090.000
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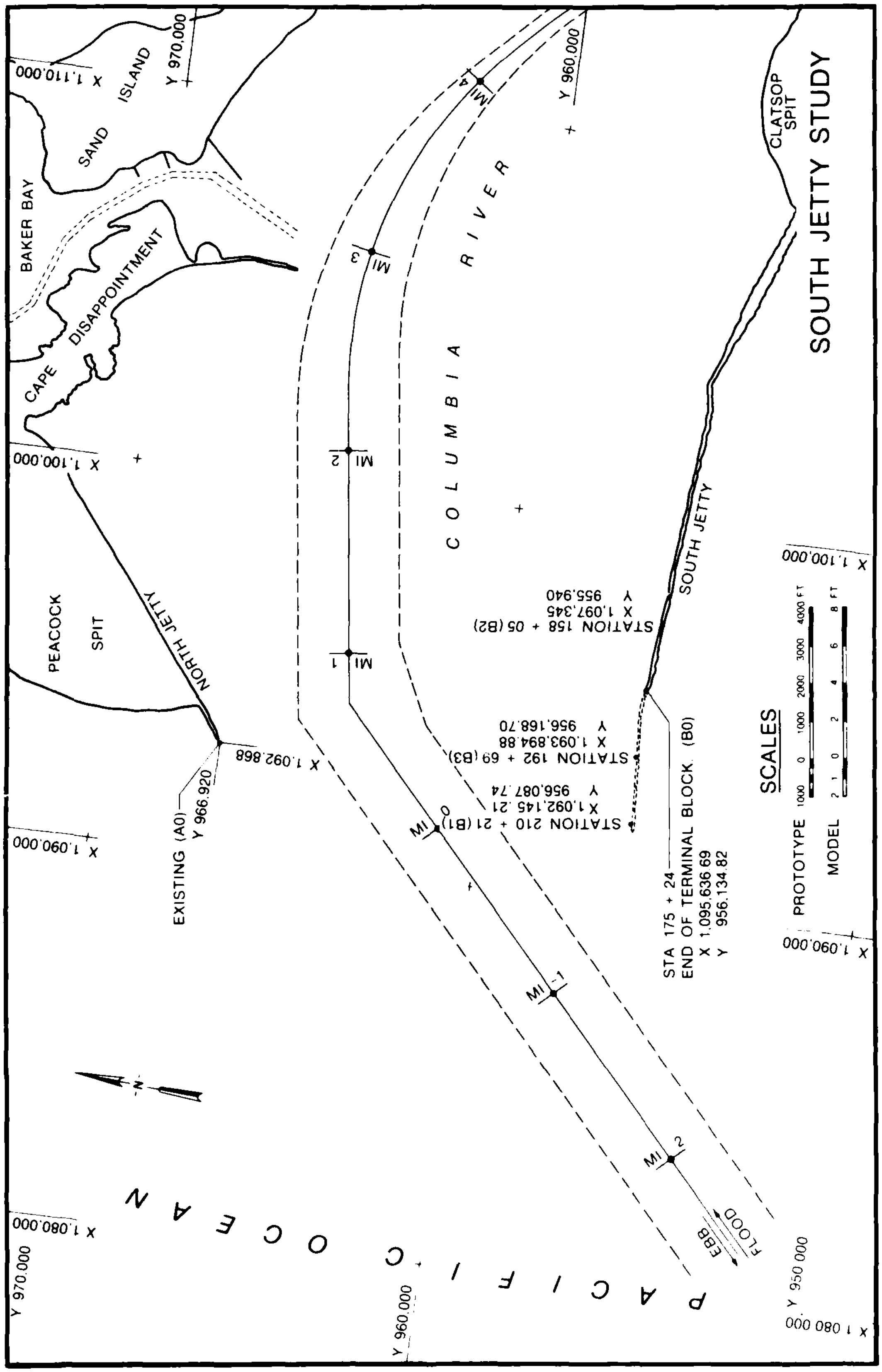
MODEL 2 1 0 2 4 6 8 FT

PLATE 1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BAKER BAY
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CAPE DISAPPOINTMENT
PEACOCK SPIT
NORTH JETTY
COLUMBIA RIVER
CLATSOP SPIT
SOUTH JETTY
PACIFIC OCEAN
EXISTING (A0)
Y 966,920
X 1,092,868
STATION 158 + 05 (B2)
X 1,097,345
Y 955,940
STATION 192 + 69 (B3)
X 1,093,894.88
Y 956,168.70
STATION 210 + 21 (B1)
X 1,092,145.21
Y 956,087.74
STA 175 + 24
END OF TERMINAL BLOCK (B0)
X 1,095,636.69
Y 956,134.82
SCALES
PROTOTYPE
MODEL
1000 0 1000 2000 3000 4000 FT
2 1 0 2 4 6 8 FT
MI 4
MI 3
MI 2
MI 1
MI 0
MI -1
MI 2
EBB
FLOOD
N
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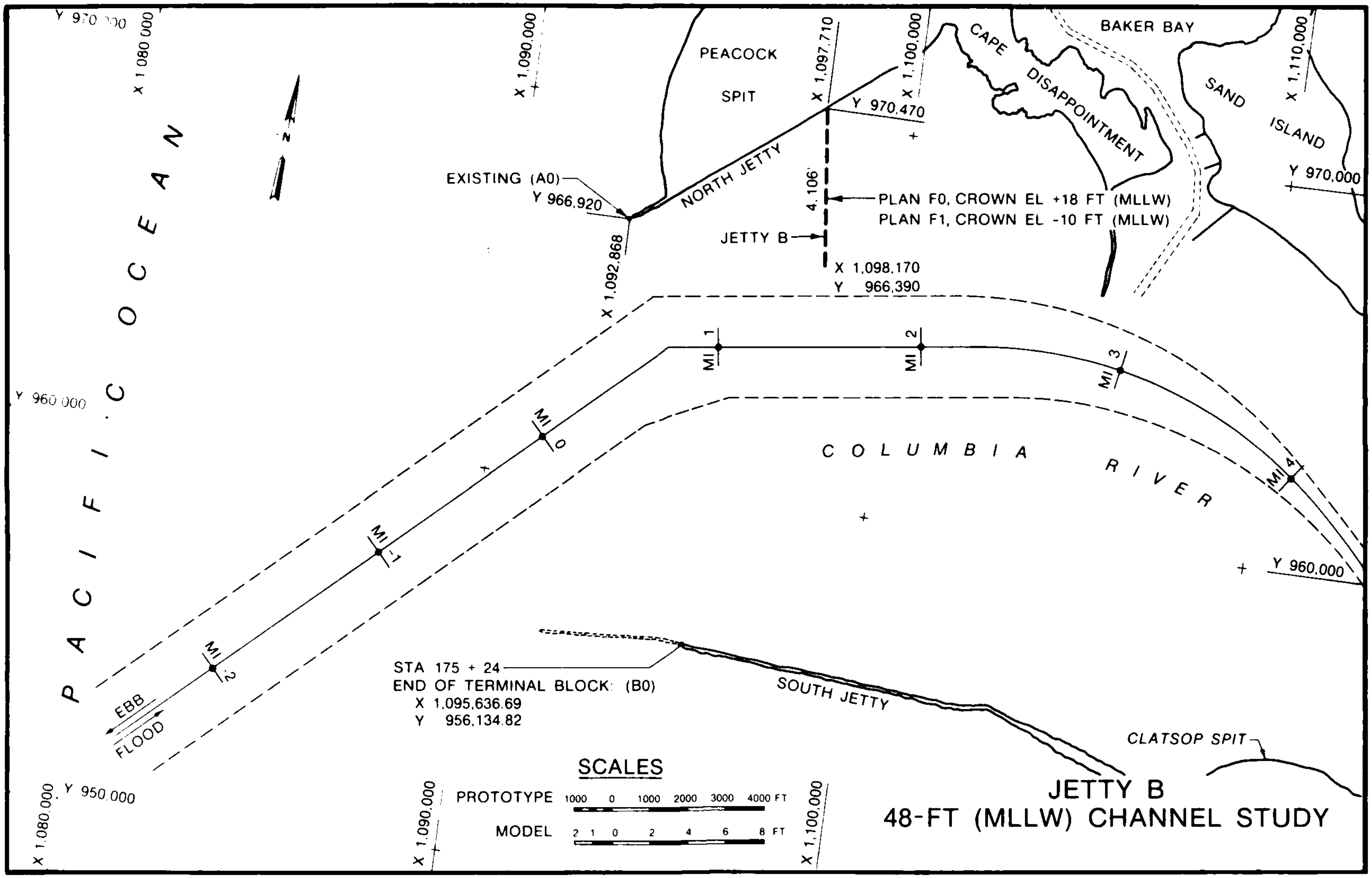
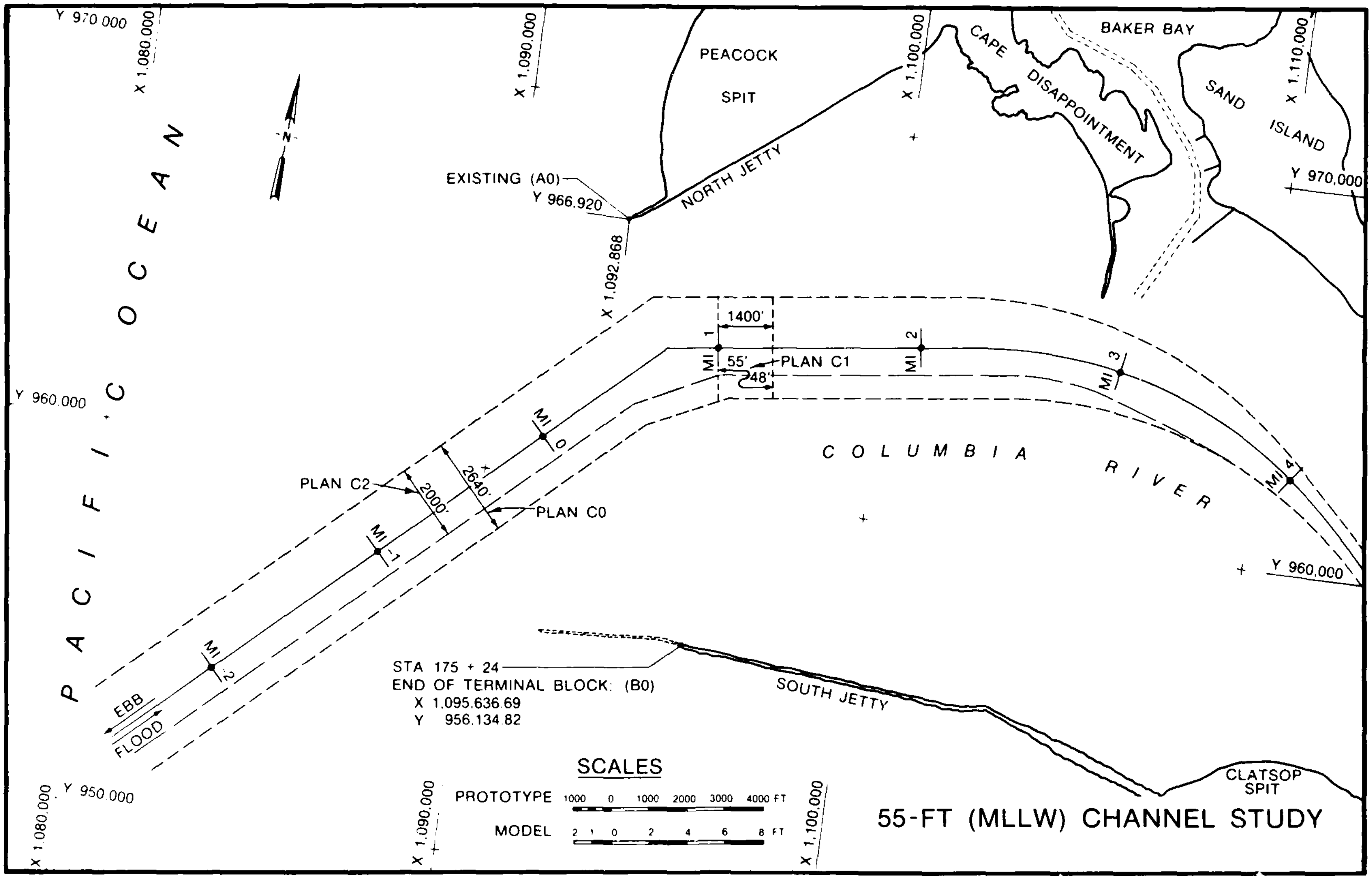
X 1,100,000
X 1,090,000
X 1,080,000
Y 970,000
Y 960,000
Y 950,000

PLATE 2



JETTY B
48-FT (MLLW) CHANNEL STUDY

PLATE 3



55-FT (MLLW) CHANNEL STUDY
PACIFIC OCEAN
COLUMBIA RIVER
PEACOCK SPIT
NORTH JETTY
CAPE DISAPPOINTMENT
BAKER BAY
SAND ISLAND
SOUTH JETTY
CLATSOP SPIT
N
EXISTING (A0)
Y 966.920
X 1.092.868
STA 175 + 24
END OF TERMINAL BLOCK: (B0)
X 1.095.636.69
Y 956.134.82
PLAN C0
PLAN C1
PLAN C2
1400'
55'
48'
2000'
2640'
MI -2
MI -1
MI 0
MI 1
MI 2
MI 3
MI 4
EBB
FLOOD
SCALES
PROTOTYPE 1000 0 1000 2000 3000 4000 FT
MODEL 2 1 0 2 4 6 8 FT
Y 970.000
Y 960.000
Y 950.000
X 1.080.000
X 1.090.000
X 1.100.000
X 1.110.000

PLATE 4

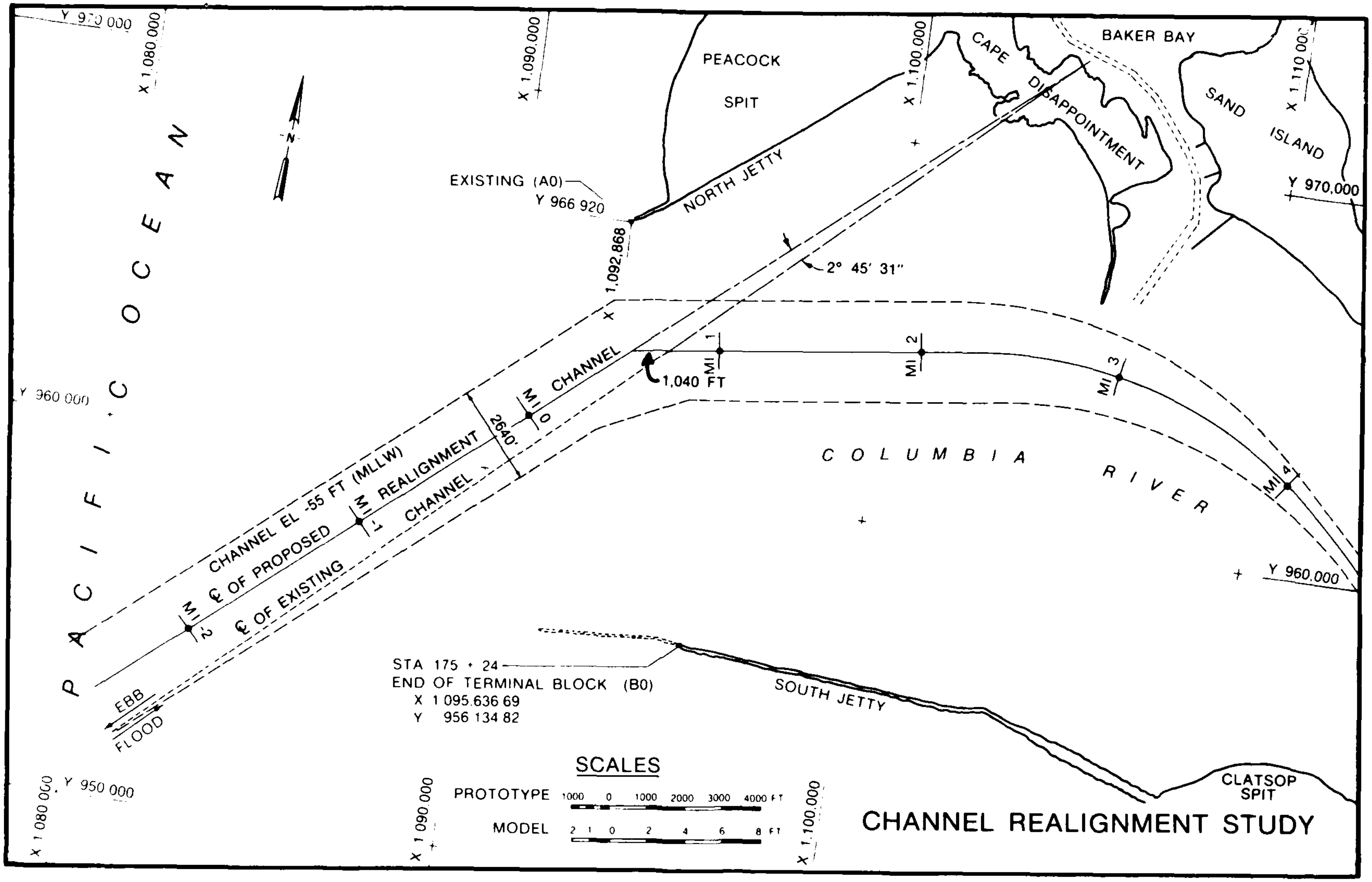

CHANNEL REALIGNMENT STUDY
PACIFIC OCEAN
COLUMBIA RIVER
PEACOCK SPIT
NORTH JETTY
CAPE DISAPPOINTMENT
BAKER BAY
SAND ISLAND
SOUTH JETTY
CLATSOP SPIT
EXISTING (A0)
Y 966 920
1,092,868
2° 45′ 31″
1,040 FT
2640′
CHANNEL EL -55 FT (MLLW)
℄ OF PROPOSED REALIGNMENT CHANNEL
℄ OF EXISTING CHANNEL
MI -2
MI -1
MI 0
MI 1
MI 2
MI 3
MI 4
EBB
FLOOD
STA 175 + 24
END OF TERMINAL BLOCK (B0)
X 1 095 636 69
Y 956 134 82
SCALES
PROTOTYPE 1000 0 1000 2000 3000 4000 FT
MODEL 2 1 0 2 4 6 8 FT
Y 970 000
Y 960 000
Y 950 000
Y 970,000
Y 960,000
X 1,080 000
X 1,090 000
X 1,100 000
X 1,110 000
N

PLATE 5

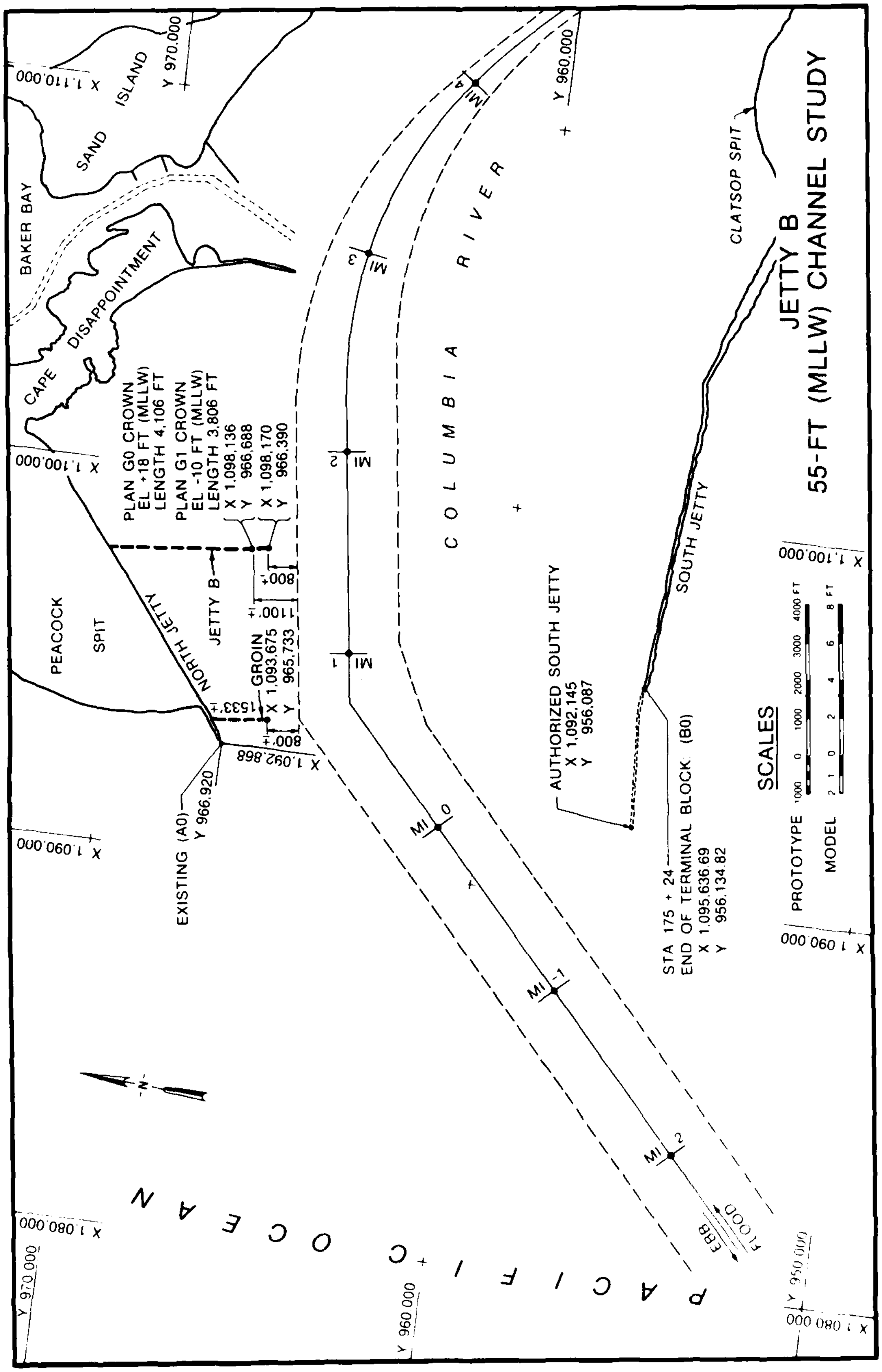
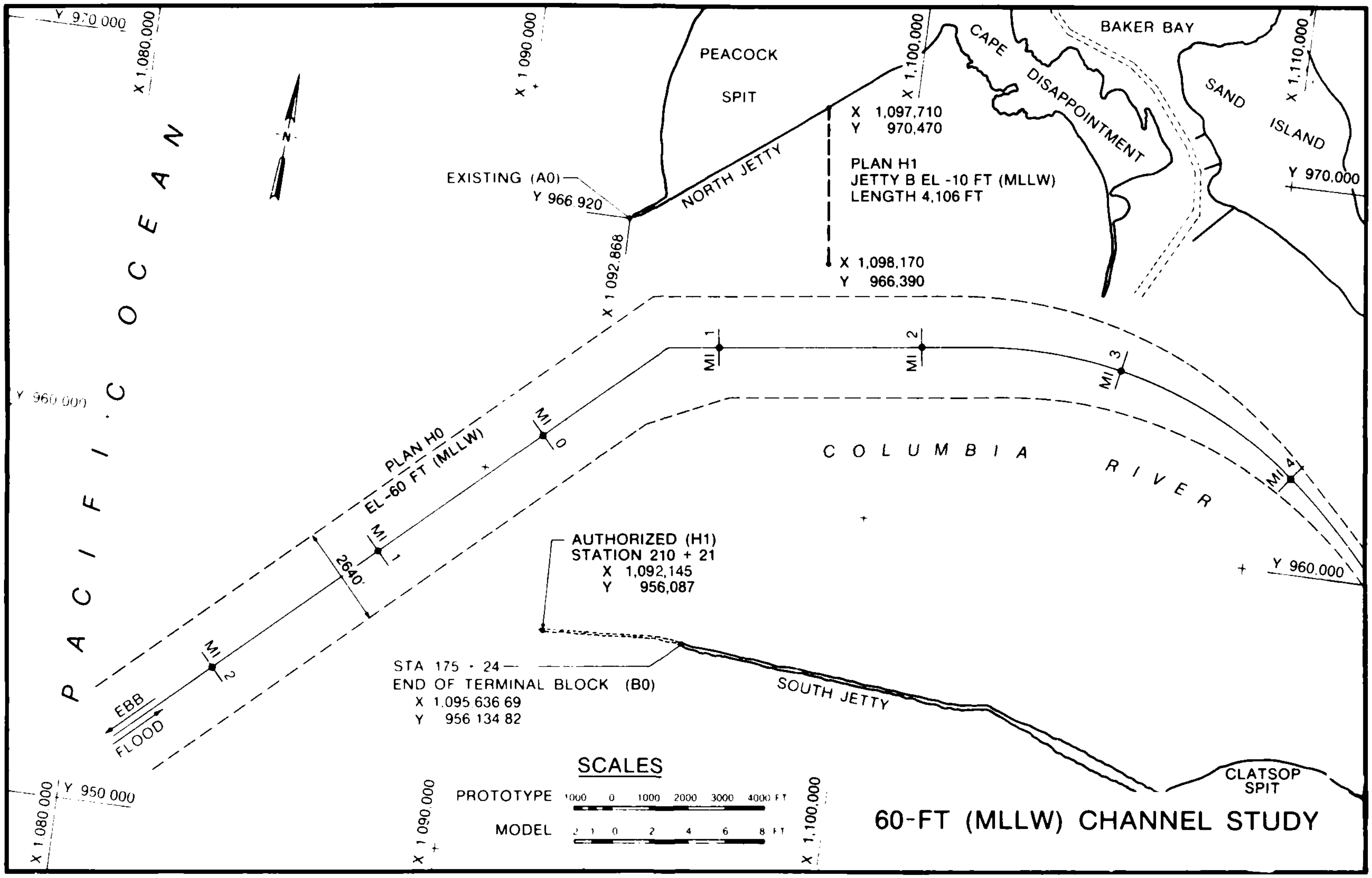
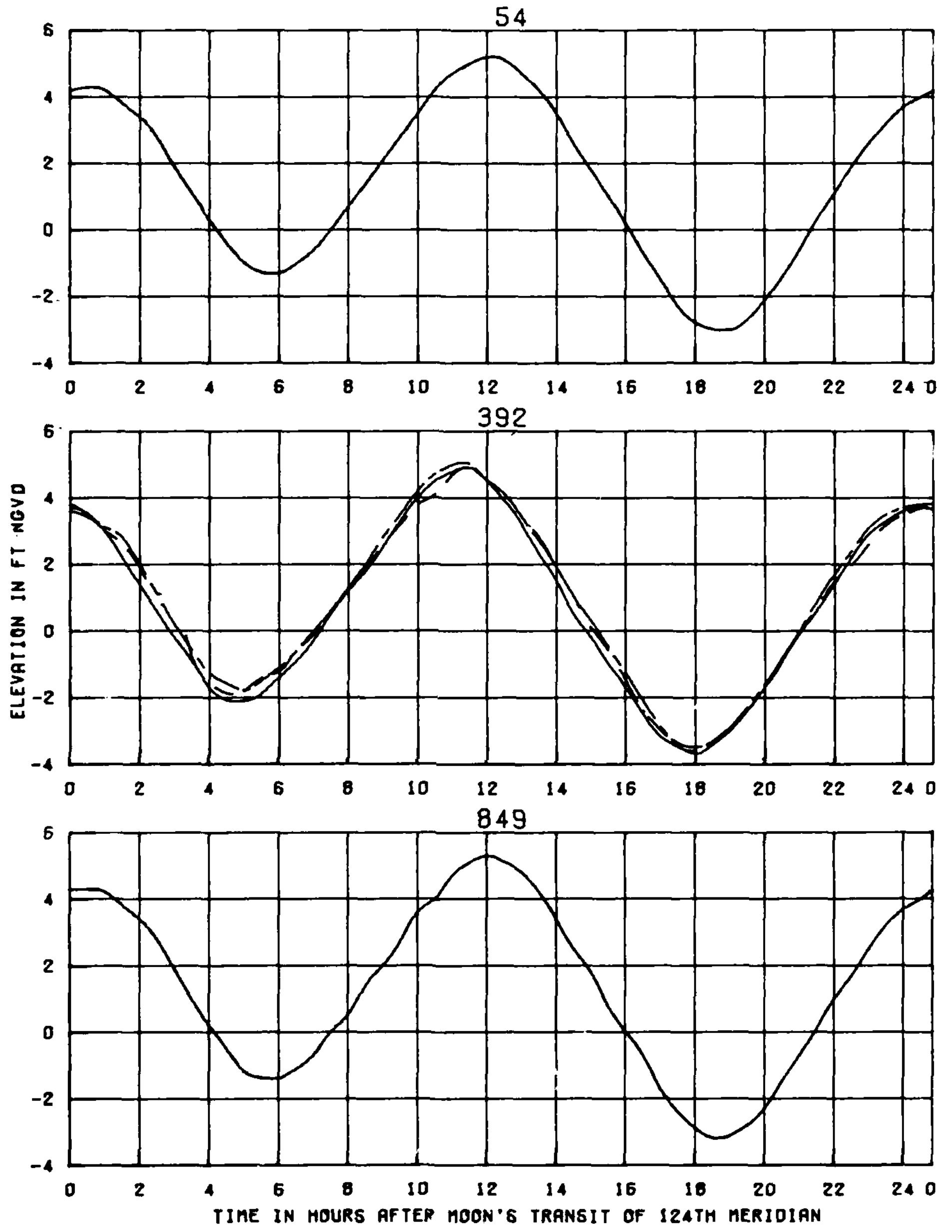

JETTY B
55-FT (MLLW) CHANNEL STUDY
PACIFIC OCEAN
COLUMBIA RIVER
BAKER BAY
SAND ISLAND
CAPE DISAPPOINTMENT
PEACOCK SPIT
NORTH JETTY
JETTY B
CLATSOP SPIT
SOUTH JETTY
PLAN G0 CROWN
EL +18 FT (MLLW)
LENGTH 4,106 FT
PLAN G1 CROWN
EL -10 FT (MLLW)
LENGTH 3,806 FT
X 1,098,136
Y 966,688
X 1,098,170
Y 966,390
GROIN
X 1,093,675
Y 965,733
1533'±
800'±
1100'±
800'±
EXISTING (A0)
Y 966,920
X 1,092,868
AUTHORIZED SOUTH JETTY
X 1,092,145
Y 956,087
STA 175 + 24
END OF TERMINAL BLOCK (B0)
X 1,095,636.69
Y 956,134.82
SCALES
PROTOTYPE
MODEL
1000 0 1000 2000 3000 4000 FT
2 1 0 2 4 6 8 FT
MI 4
MI 3
MI 2
MI 1
MI 0
MI -1
MI 2
EBB
FLOOD
N
X 1,110,000
X 1,100,000
X 1,090,000
X 1,080,000
Y 970,000
Y 960,000
Y 950,000

PLATE 6



PACIFIC OCEAN
N
PEACOCK SPIT
NORTH JETTY
EXISTING (A0)
Y 966 920
X 1 092 868
X 1,097,710
Y 970,470
PLAN H1
JETTY B EL -10 FT (MLLW)
LENGTH 4,106 FT
X 1,098,170
Y 966,390
CAPE DISAPPOINTMENT
BAKER BAY
SAND ISLAND
Y 970,000
PLAN H0
EL -60 FT (MLLW)
2640'
MI 2
MI 1
MI 0
MI 1
MI 2
MI 3
MI 4
EBB
FLOOD
COLUMBIA RIVER
AUTHORIZED (H1)
STATION 210 + 21
X 1,092,145
Y 956,087
STA 175 + 24
END OF TERMINAL BLOCK (B0)
X 1,095 636 69
Y 956 134 82
SOUTH JETTY
CLATSOP SPIT
Y 960,000
Y 970 000
Y 960 000
Y 950 000
X 1,080,000
X 1,090,000
X 1,100,000
X 1,110,000
SCALES
PROTOTYPE 1000 0 1000 2000 3000 4000 FT
MODEL 2 1 0 2 4 6 8 FT
60-FT (MLLW) CHANNEL STUDY

PLATE 7



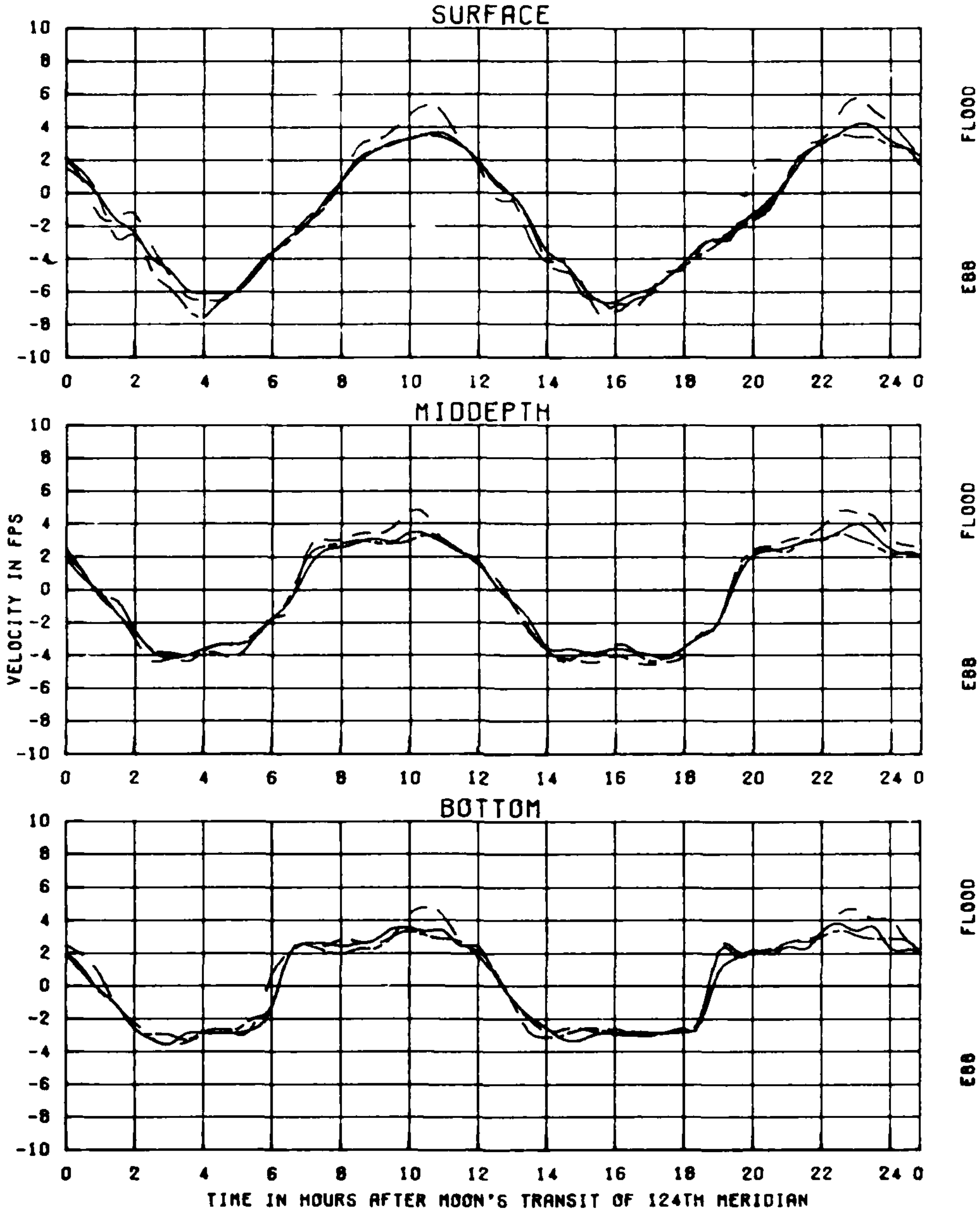
TEST CONDITIONS

TIDAL RANGE AT STATION 406	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

LEGEND
BASE ————
PLAN A1 — — —
PLAN A2 —·—

NORTH JETTY STUDY
48-FT (MLLW) CHANNEL

EFFECTS OF
PLANS A1 AND A2
ON TIDAL HEIGHTS
STATIONS
54, 392, AND 849



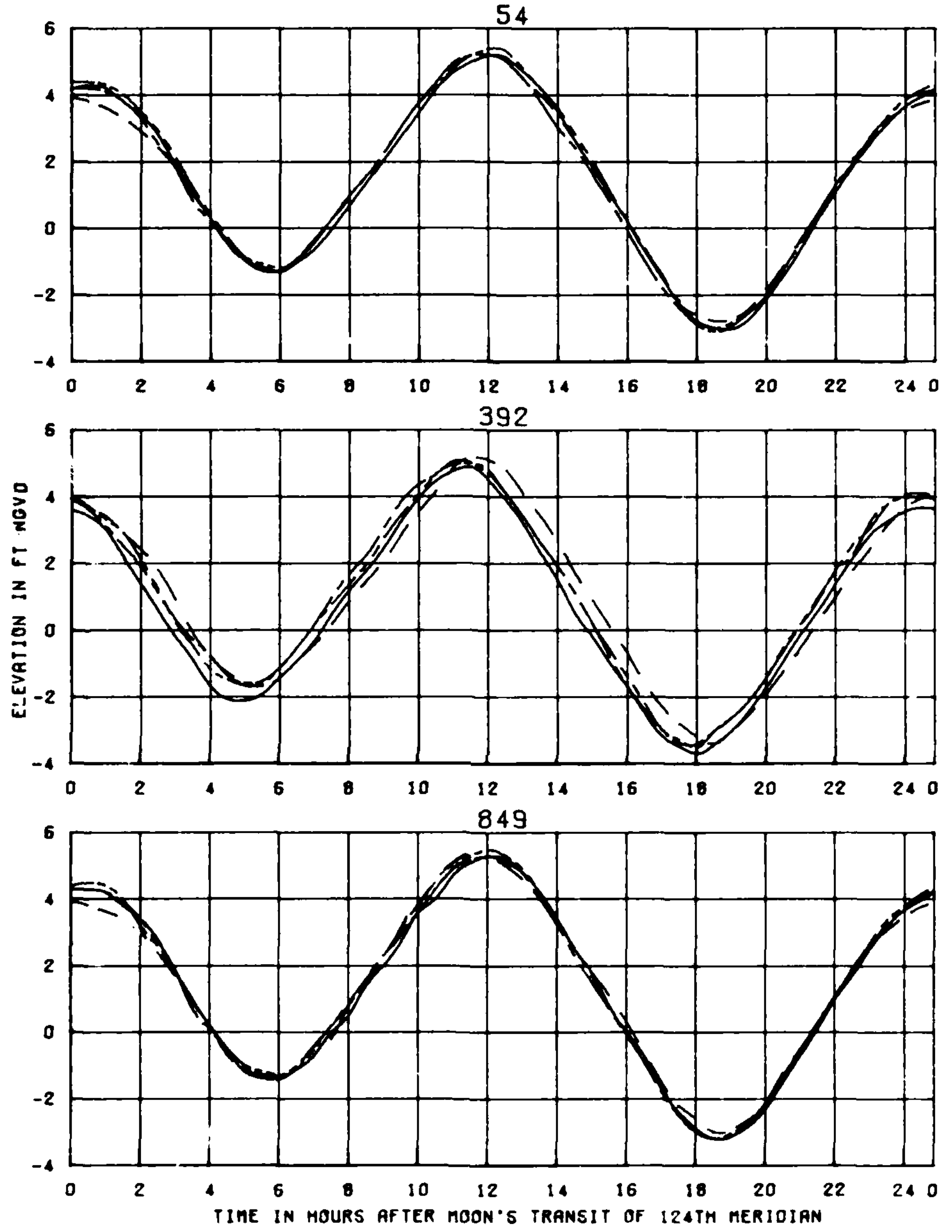
TEST CONDITIONS

TIDAL RANGE AT STATION 406	8.85 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

NORTH JETTY STUDY
48-FT (MLLW) CHANNEL

EFFECTS OF
PLANS A1 AND A2
ON VELOCITIES
STATION
286

LEGEND
BASE ———
PLAN A1 — — —
PLAN A2 —·—·—



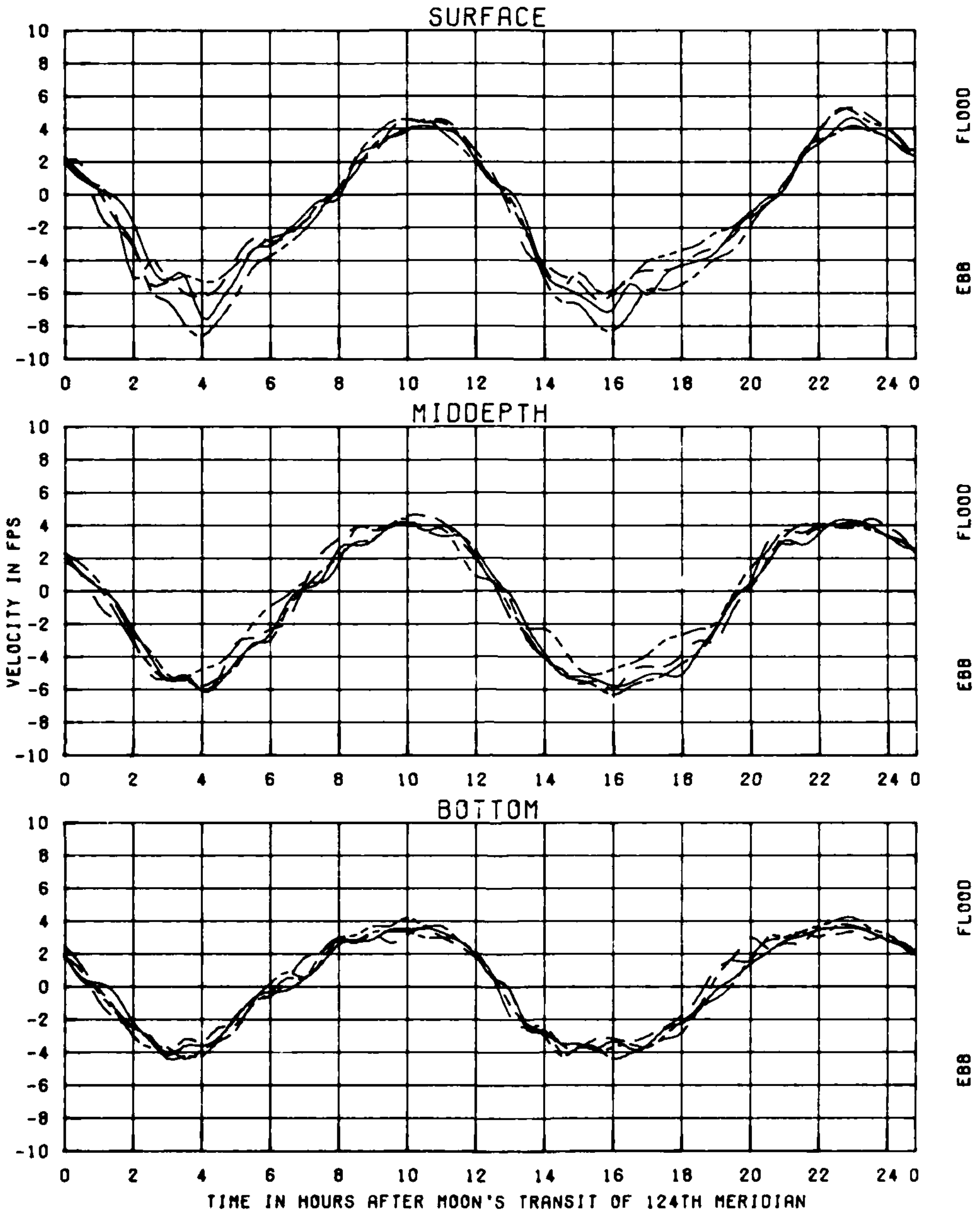
TEST CONDITIONS

TIDAL RANGE AT STATION 406	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

SOUTH JETTY STUDY
48-FT (MLLW) CHANNEL

EFFECTS OF
PLANS B1, B2, AND B3
ON TIDAL HEIGHTS
STATIONS
54, 392, AND 849

LEGEND
BASE
PLAN B1
PLAN B2
PLAN B3



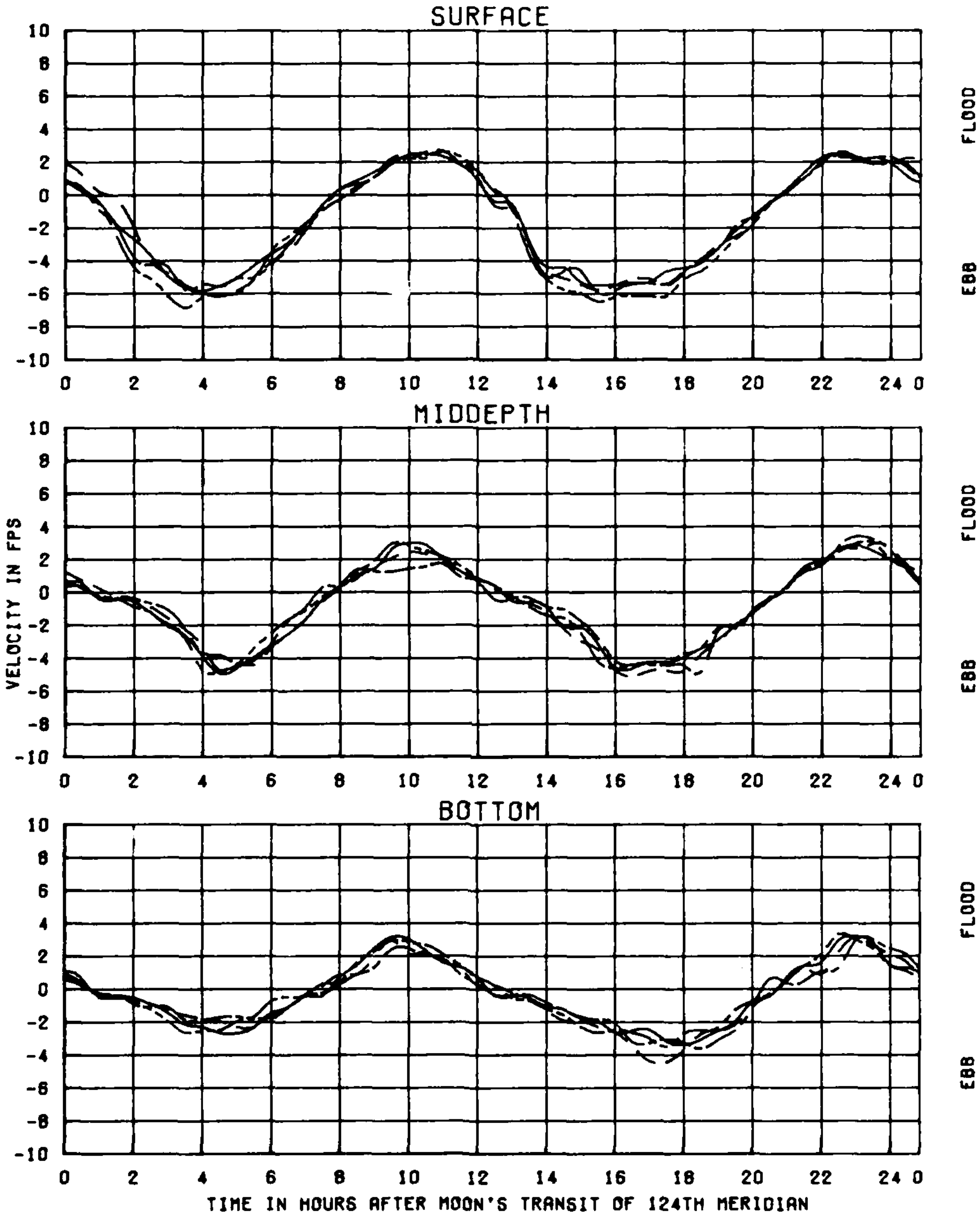
TEST CONDITIONS

TIDAL RANGE AT STATION 406	8.95 FT	
OCEAN SALINITY (TOTAL SALT)	33.0 PPT	
FRESH WATER DISCHARGE	300,000.0 CFS	

LEGEND
BASE ————
PLAN B1 — — — -
PLAN B2 —·—·—
PLAN B3 —----—

SOUTH JETTY STUDY
48-FT (MLLW) CHANNEL

EFFECTS OF
PLANS B1, B2, AND B3
ON VELOCITIES
STATION
127

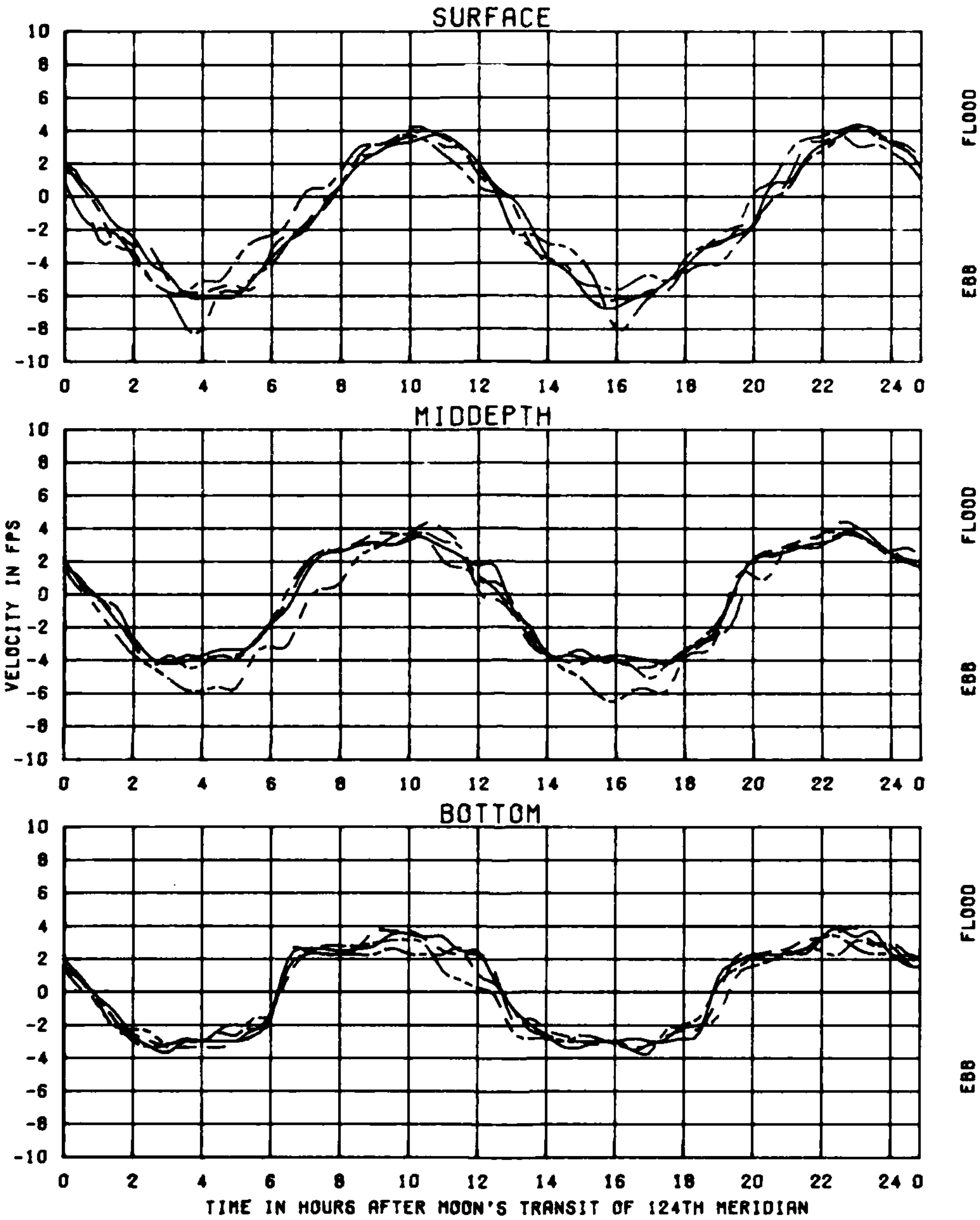


TEST CONDITIONS	
TIDAL RANGE AT STATION 406	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

SOUTH JETTY STUDY
48-FT (MLLW) CHANNEL

EFFECTS OF
PLANS B1, B2, AND B3
ON VELOCITIES
STATION
160

LEGEND
BASE ————
PLAN B1 — — —
PLAN B2 —-—
PLAN B3 —--—



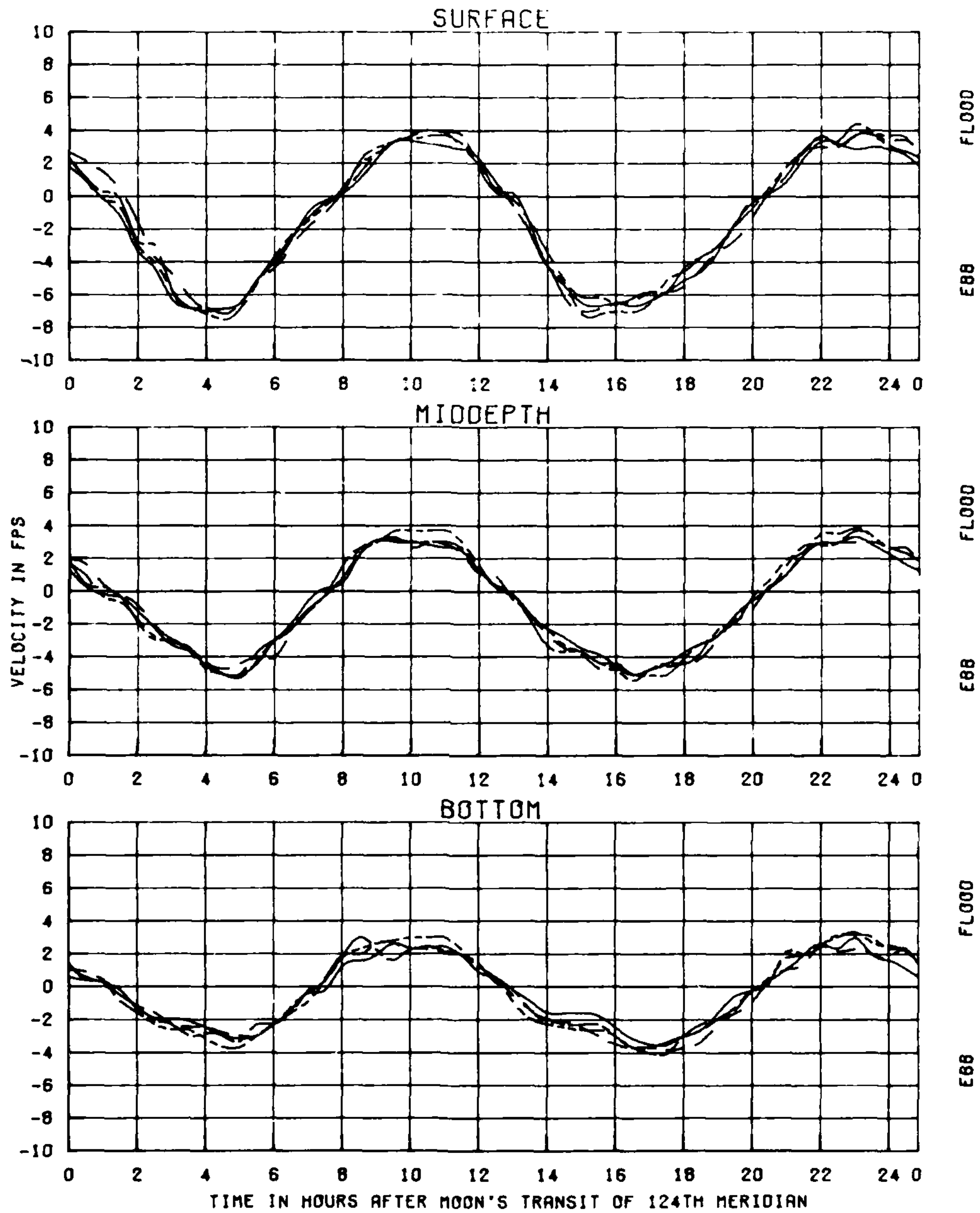
TEST CONDITIONS

TIDAL RANGE AT STATION 406	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

LEGEND
BASE ———
PLAN B1 — — —
PLAN B2 —-—-
PLAN B3 —··—

SOUTH JETTY STUDY
48-FT (MLLW) CHANNEL

EFFECTS OF
PLANS B1, B2, AND B3
ON VELOCITIES
STATION
286



TEST CONDITIONS

TIDAL RANGE AT STATION 406	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

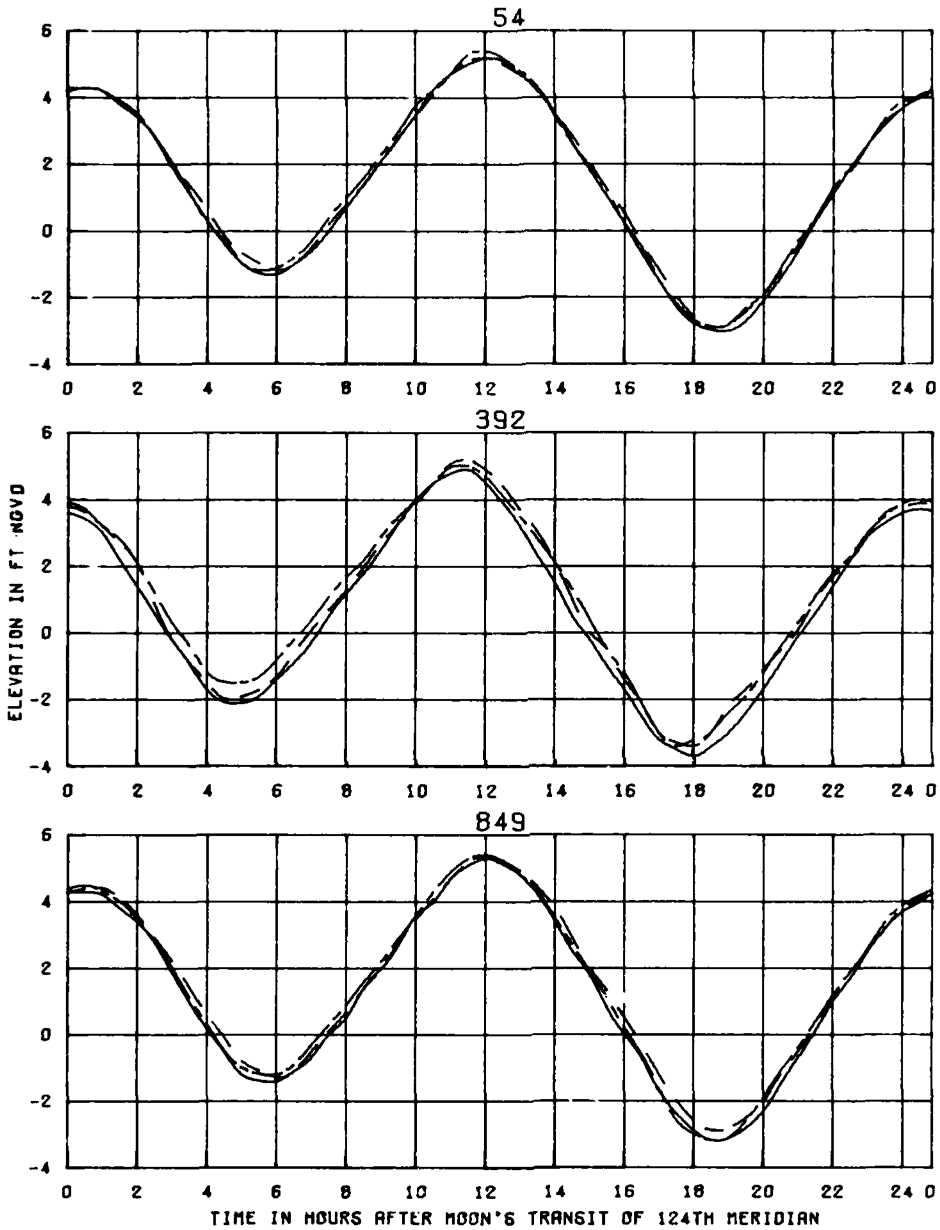
LEGEND

BASE ————
PLAN B1 — — —
PLAN B2 ------
PLAN B3 -·-·-·

SOUTH JETTY STUDY
48-FT (MLLW) CHANNEL

EFFECTS OF
PLANS B1, B2, AND B3
ON VELOCITIES

STATION
823



TEST CONDITIONS

TIDAL RANGE AT STATION 406	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

LEGEND

BASE ————

PLAN F0 — — —

PLAN F1 —·—·—

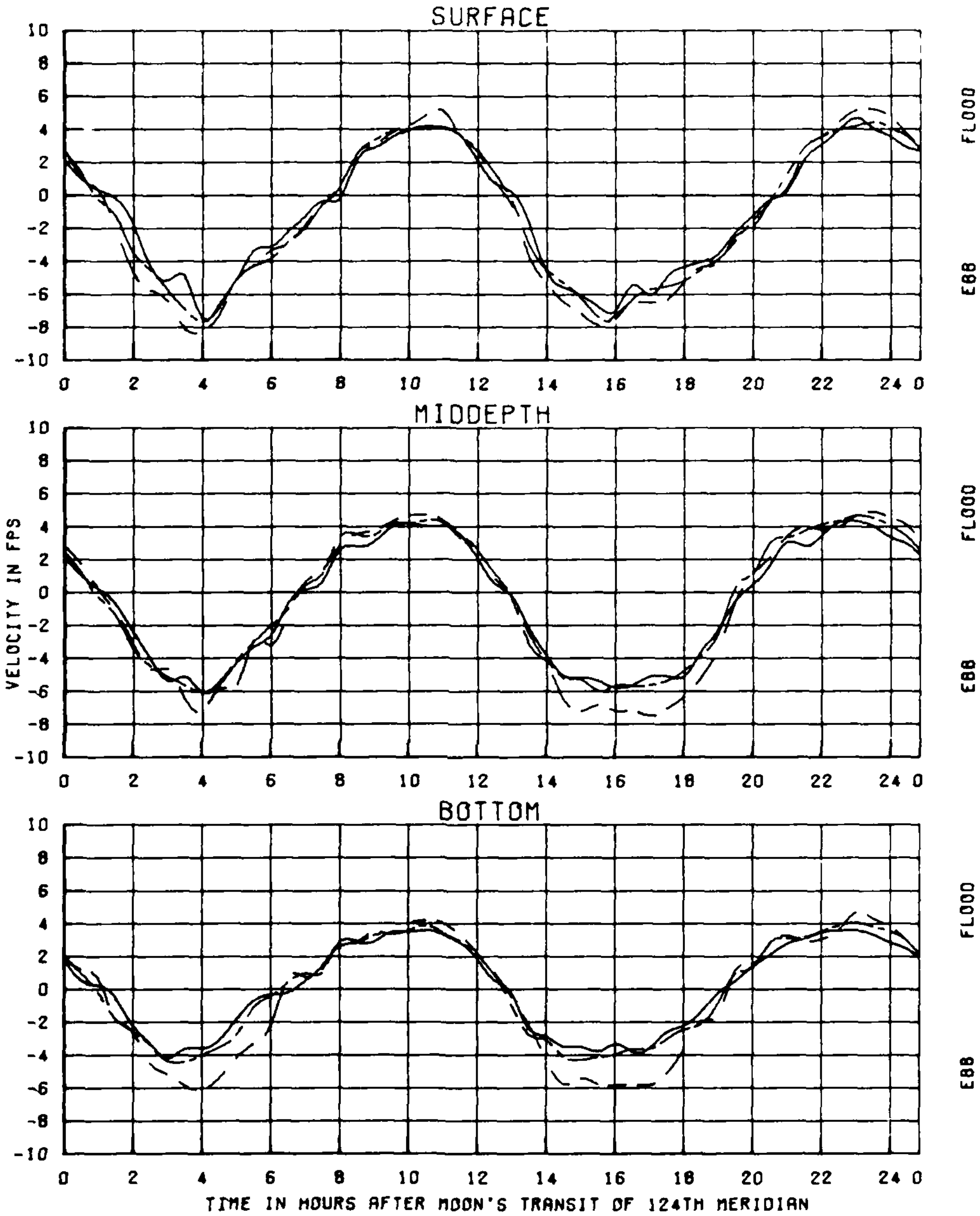
JETTY B STUDY

48-FT (MLLW) CHANNEL

EFFECTS OF PLANS F0 AND F1 ON TIDAL HEIGHTS

STATIONS

54, 392, AND 849



TEST CONDITIONS

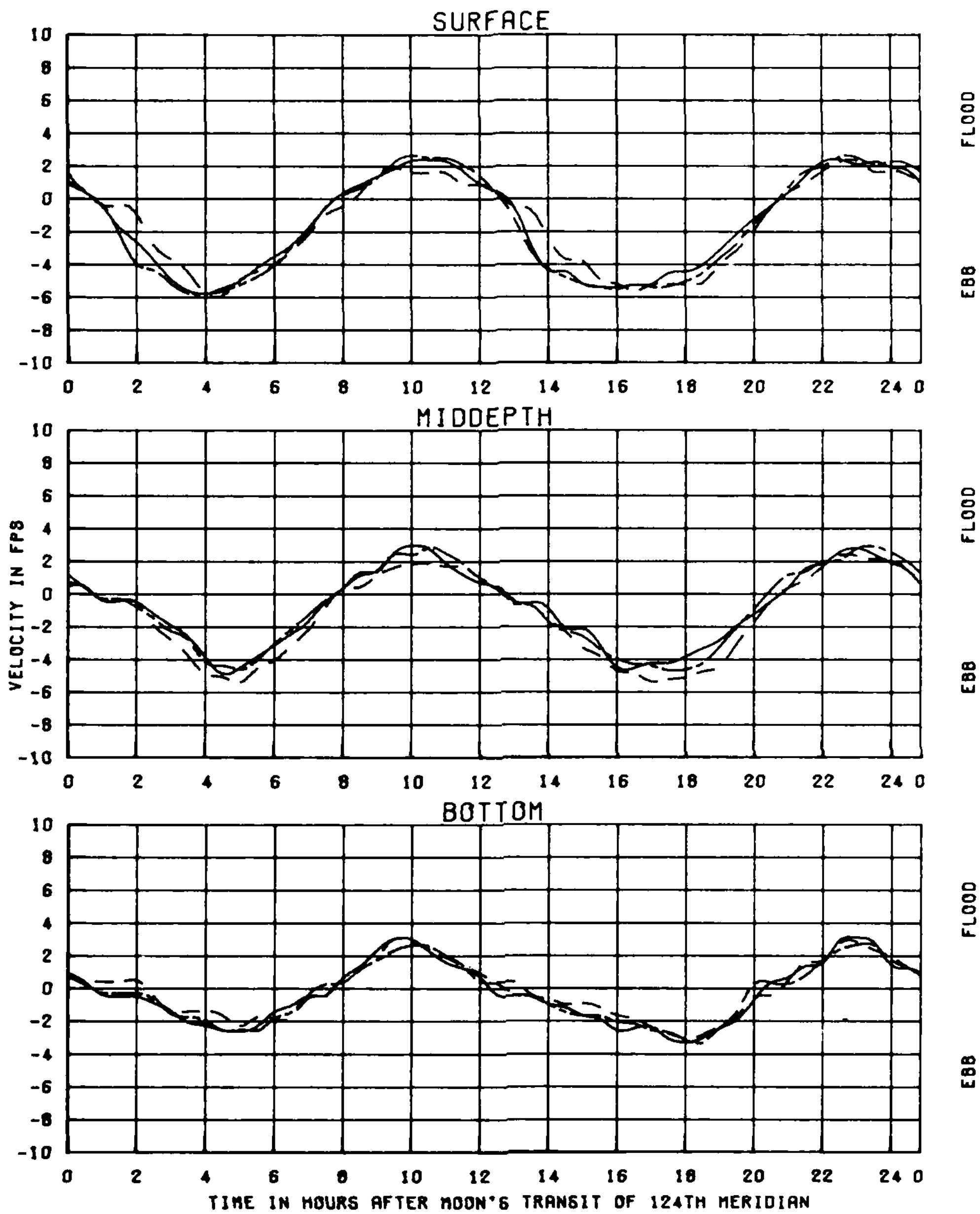
TIDAL RANGE AT STATION 406	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

JETTY B STUDY
48-FT (MLLW) CHANNEL

EFFECTS OF
PLANS F0 AND F1
ON VELOCITIES

STATION
127

LEGEND
BASE ———
PLAN F0 — — —
PLAN F1 —·—·—



TEST CONDITIONS

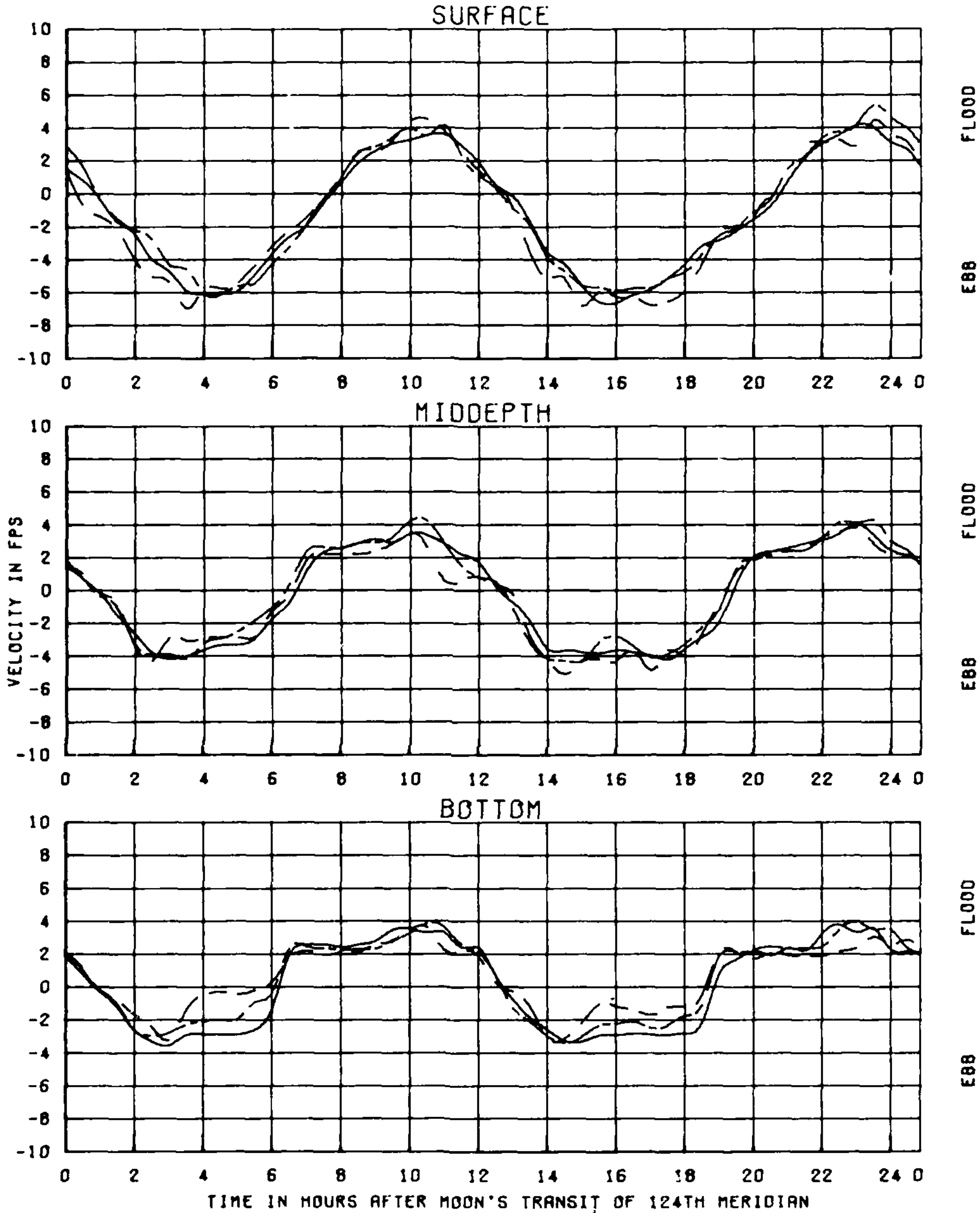
TIDAL RANGE AT STATION 406	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

LEGEND
BASE ———
PLAN F0 — — —
PLAN F1 —·—·—

JETTY B STUDY
48-FT (MLLW) CHANNEL

EFFECTS OF PLANS F0 AND F1 ON VELOCITIES

STATION
160



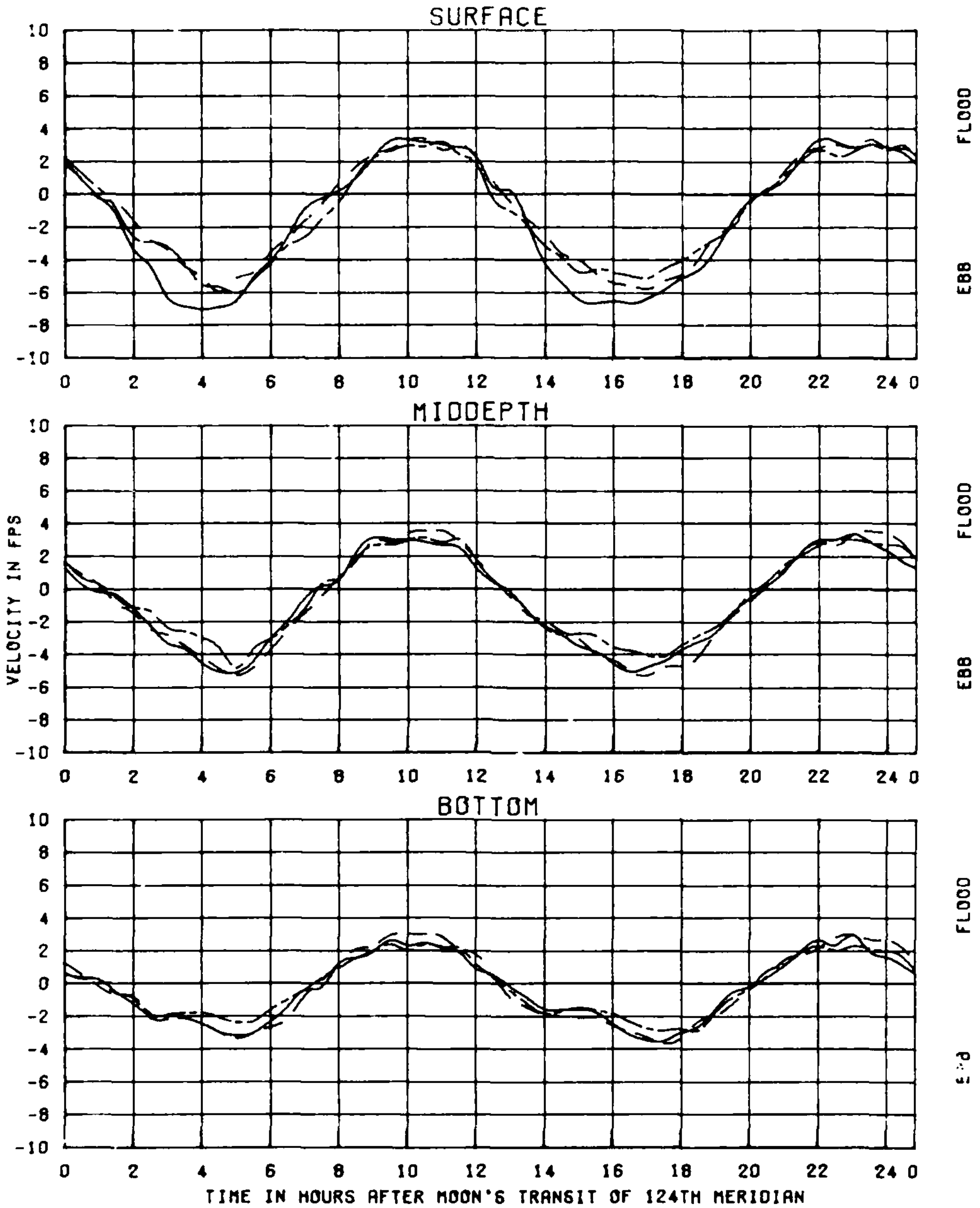
TEST CONDITIONS	
TIDAL RANGE AT STATION 406	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

JETTY B STUDY
48-FT (MLLW) CHANNEL

EFFECTS OF
PLANS F0 AND F1
ON VELOCITIES
STATION
286

LEGEND
BASE ————
PLAN F0 — — —
PLAN F1 - ---- —

PLATE 18

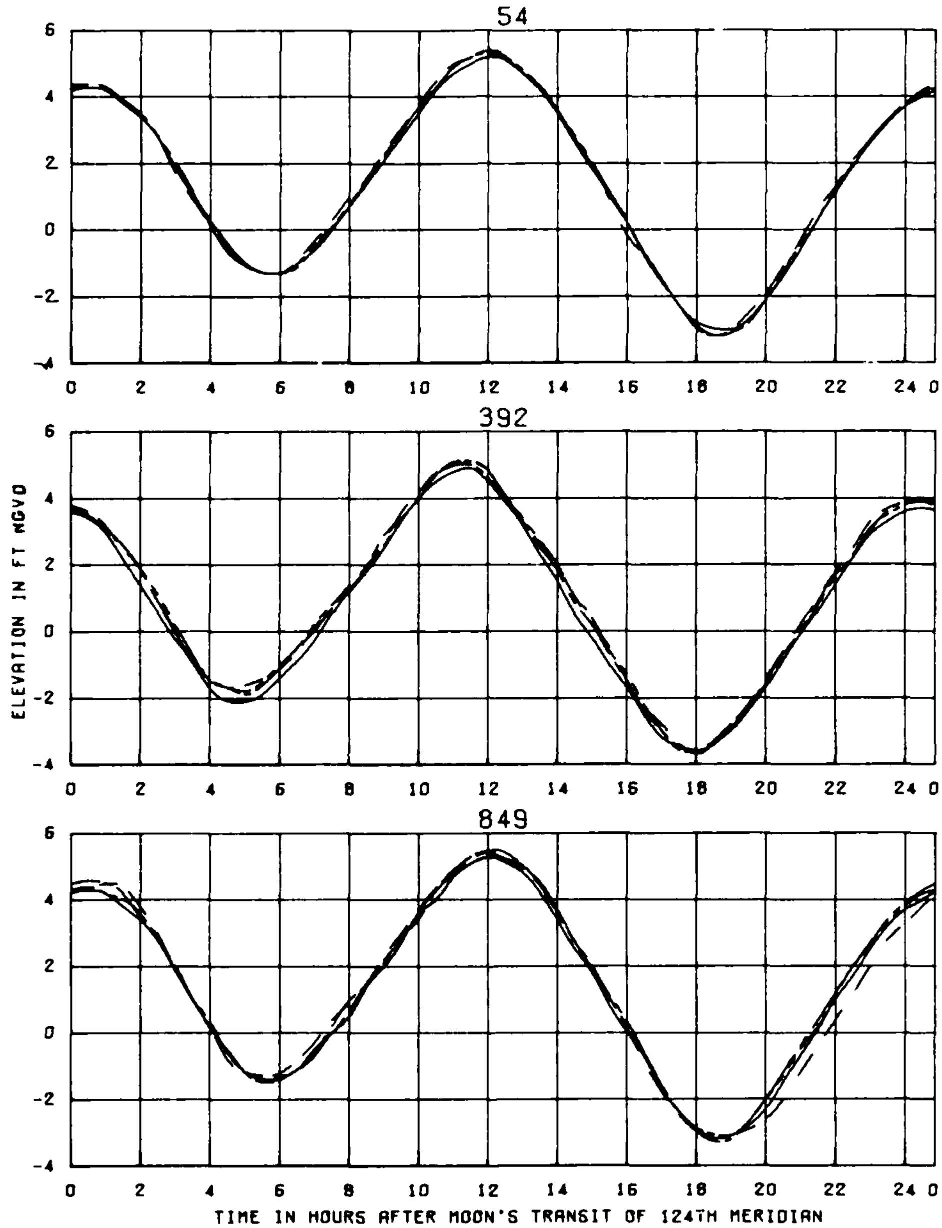


TEST CONDITIONS	
TIDAL RANGE AT STATION 406	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

LEGEND
BASE ————
PLAN F0 — — —
PLAN F1 —-—-

JETTY B STUDY
48-FT (MLLW) CHANNEL

EFFECTS OF
PLANS F0 AND F1
ON VELOCITIES
STATION
823



TEST CONDITIONS

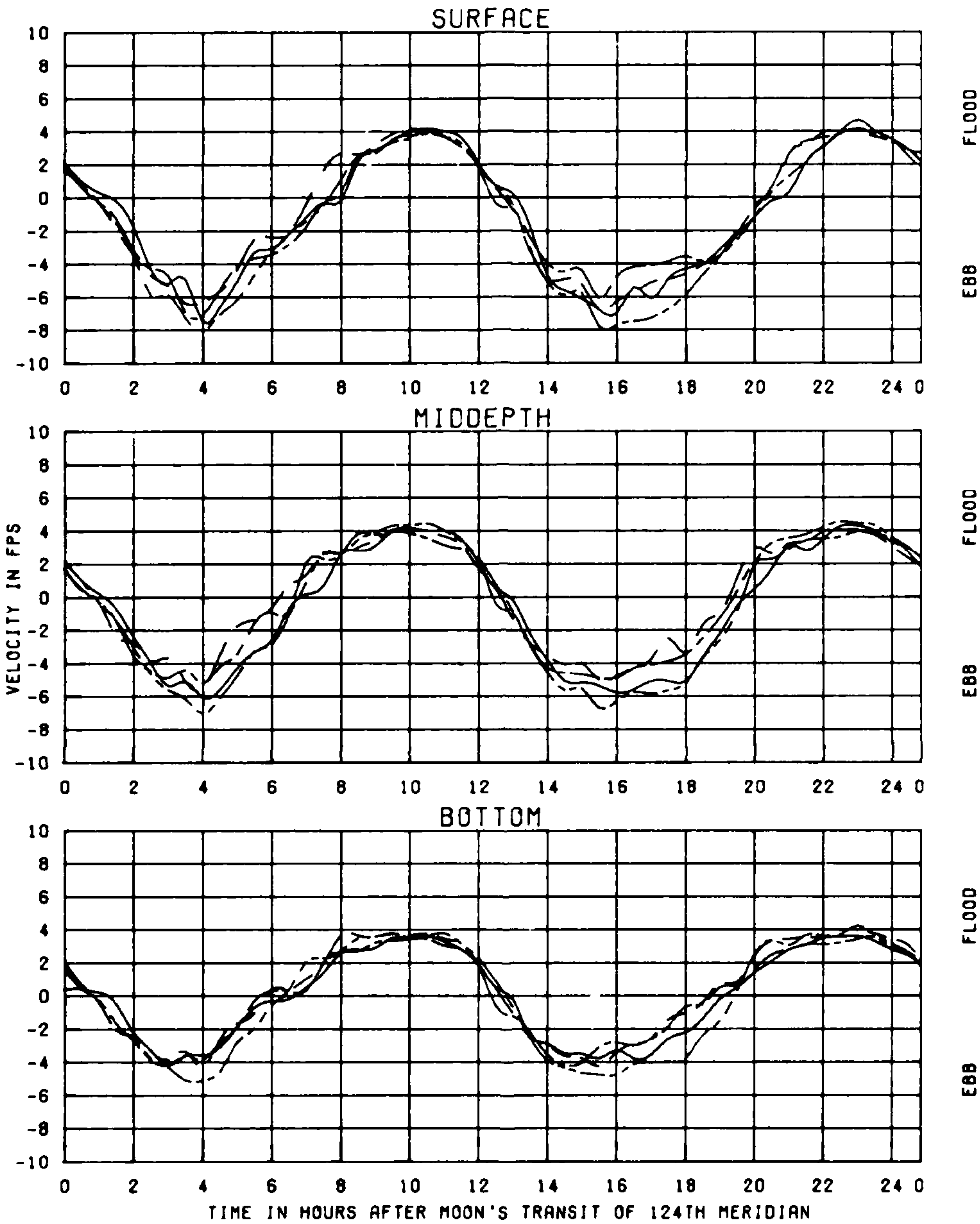
TIDAL RANGE AT STATION 406	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

55-FT (MLLW) CHANNEL STUDY

EFFECTS OF
PLANS C0, C1, AND C2
ON TIDAL HEIGHTS

STATIONS
54, 392, AND 849

LEGEND
BASE
PLAN C0
PLAN C1
PLAN C2



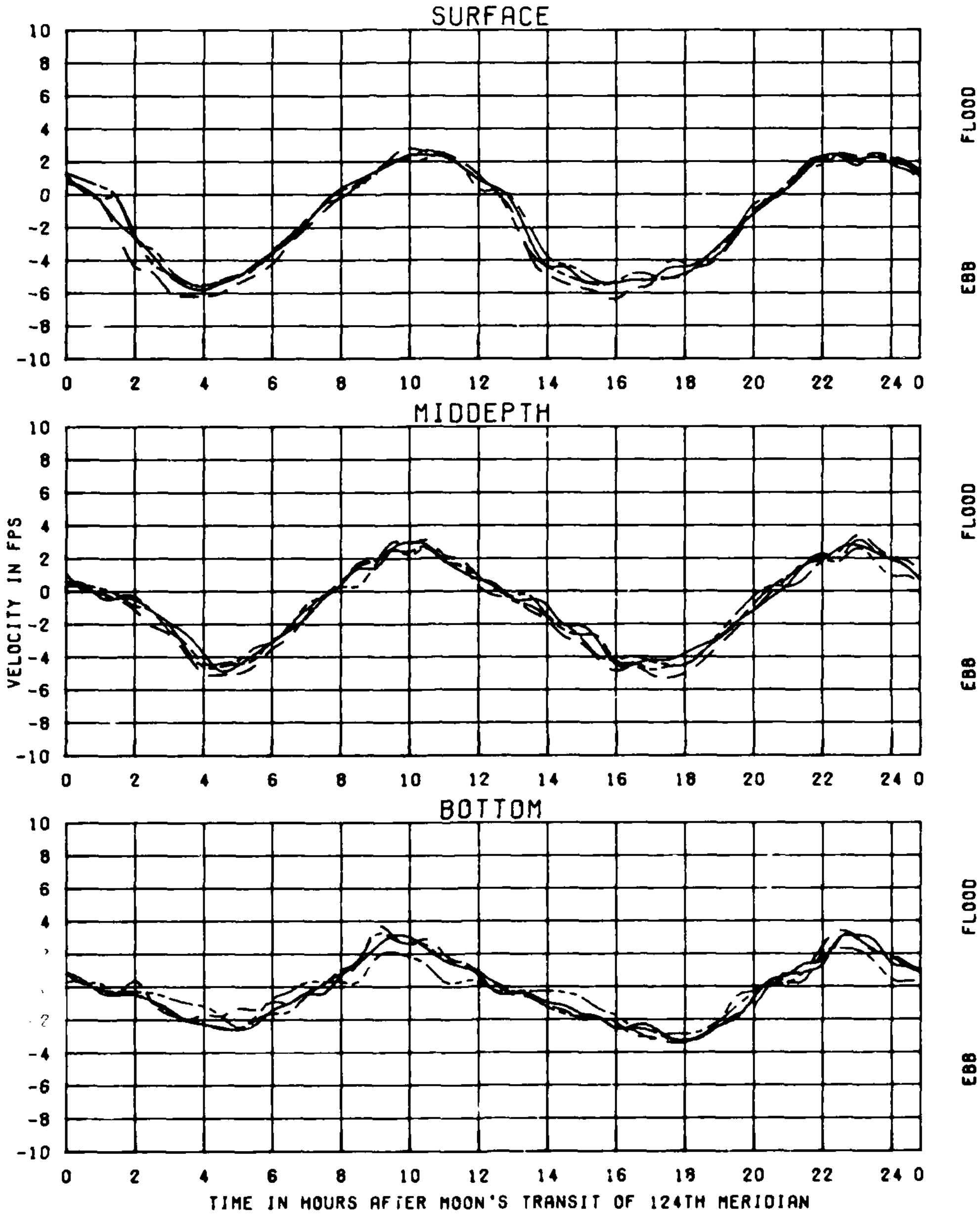
TEST CONDITIONS

TIDAL RANGE AT STATION 406 — 8.95 FT
OCEAN SALINITY (TOTAL SALT) — 33.0 PPT
FRESH WATER DISCHARGE — 300,000.0 CFS

LEGEND
BASE ————
PLAN C0 — — —
PLAN C1 —·—·—
PLAN C2 —··—··—

55-FT (MLLW) CHANNEL STUDY

EFFECTS OF
PLANS C0, C1, AND C2
ON VELOCITIES
STATION
127



TEST CONDITIONS

TIDAL RANGE AT STATION 406	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

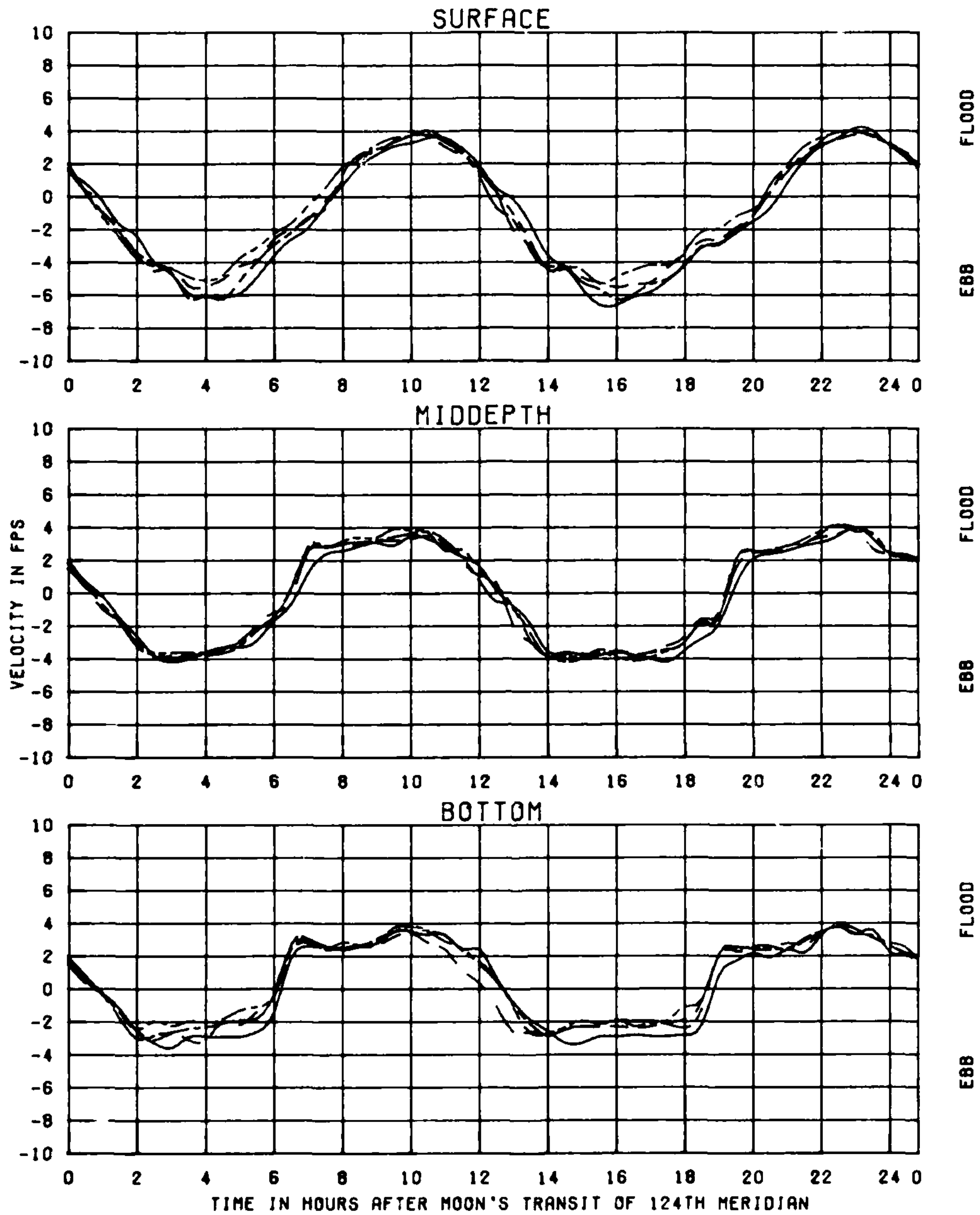
55-FT (MLLW) CHANNEL STUDY

EFFECTS OF
PLANS C0, C1, AND C2
ON VELOCITIES

STATION
160

LEGEND
BASE
PLAN C0
PLAN C1
PLAN C2

PLATE 22



TEST CONDITIONS

TIDAL RANGE AT STATION 406	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

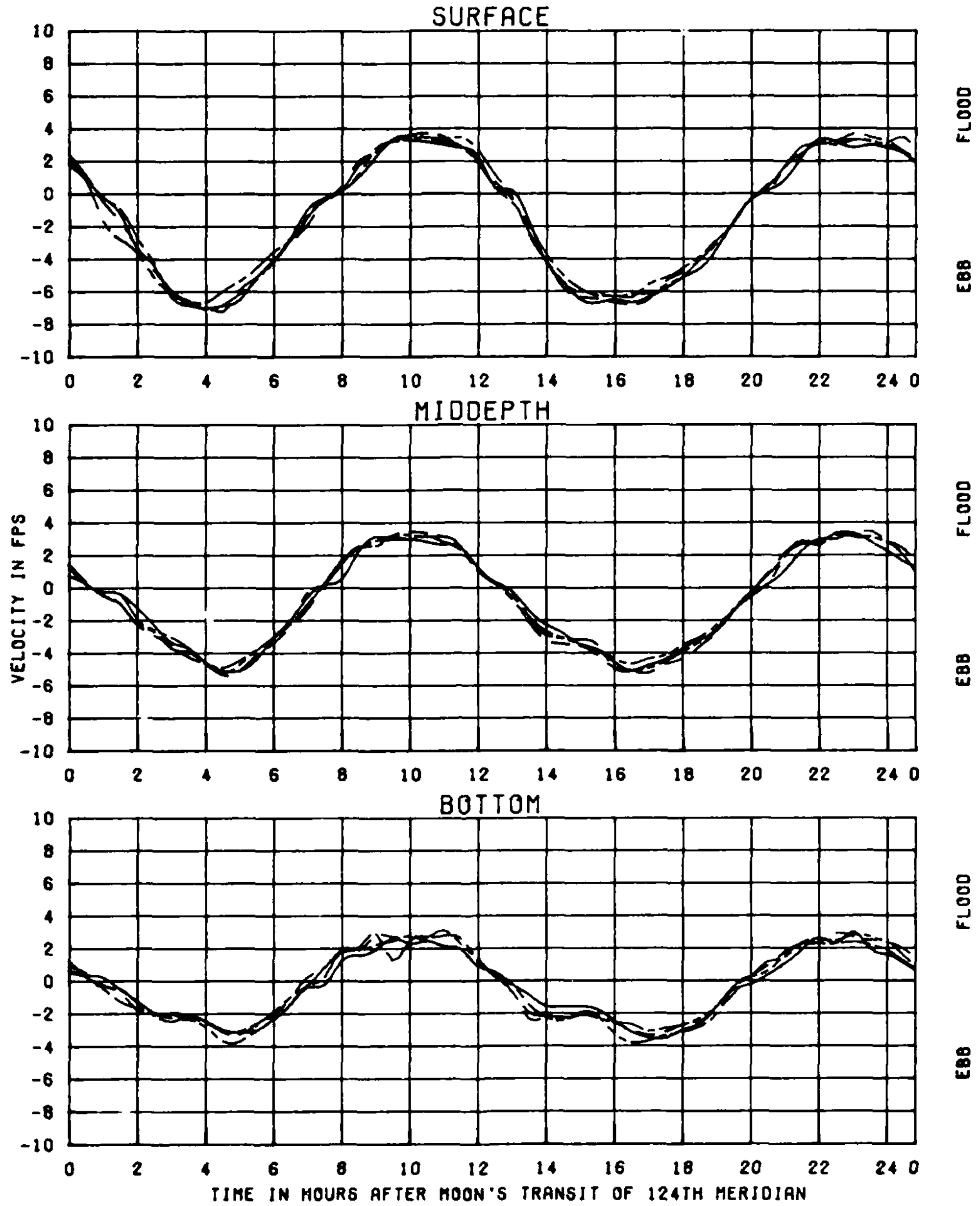
LEGEND

BASE ———
PLAN C0 — — —
PLAN C1 —·—
PLAN C2 —··—

55-FT (MLLW) CHANNEL STUDY

EFFECTS OF
PLANS C0, C1, AND C2
ON VELOCITIES

STATION
286



TEST CONDITIONS

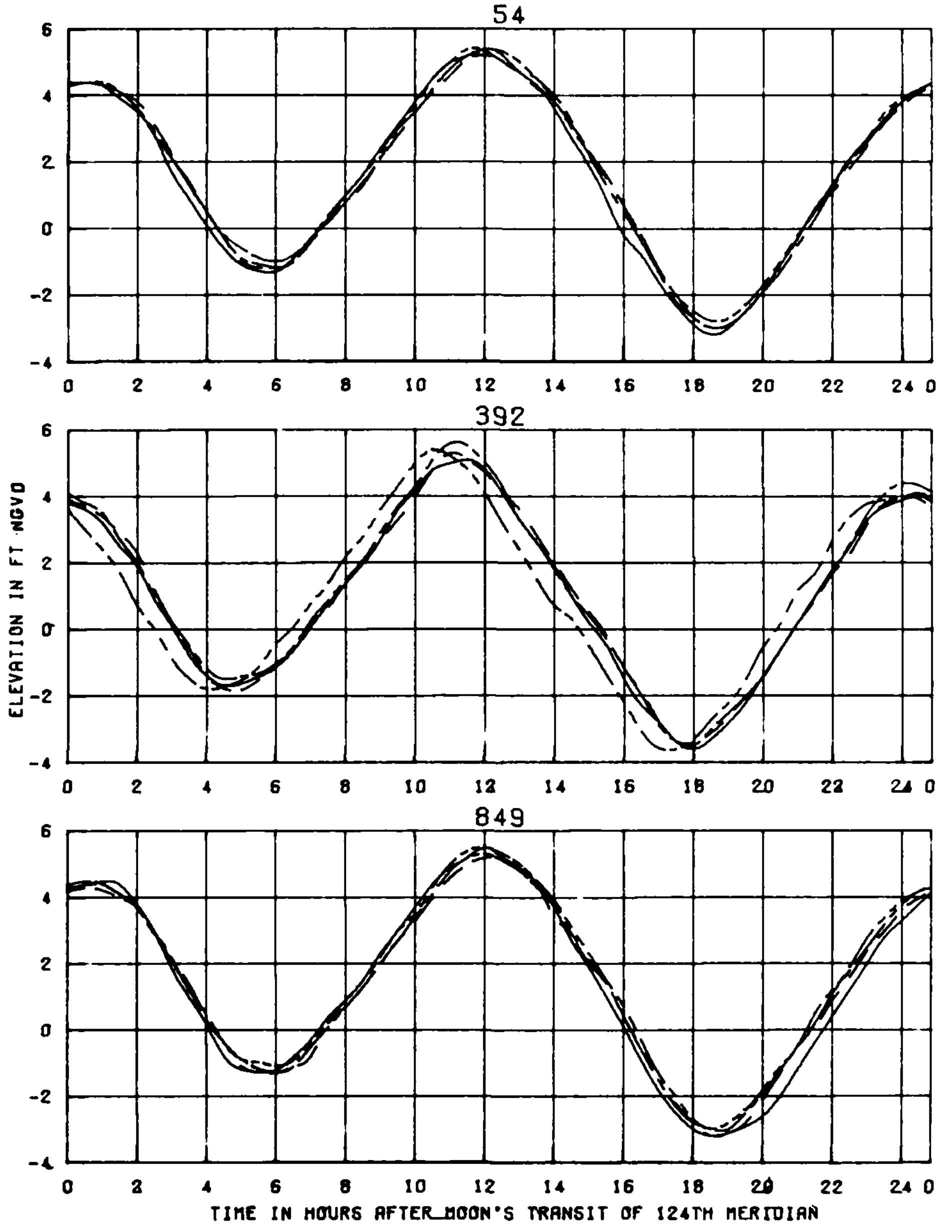
TIDAL RANGE AT STATION 406	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

LEGEND
BASE ———
PLAN C0 — — —
PLAN C1 —·—·—
PLAN C2 ----—

55-FT (MLLW) CHANNEL STUDY

EFFECTS OF
PLANS C0, C1, AND C2
ON VELOCITIES

STATION
823



TEST CONDITIONS

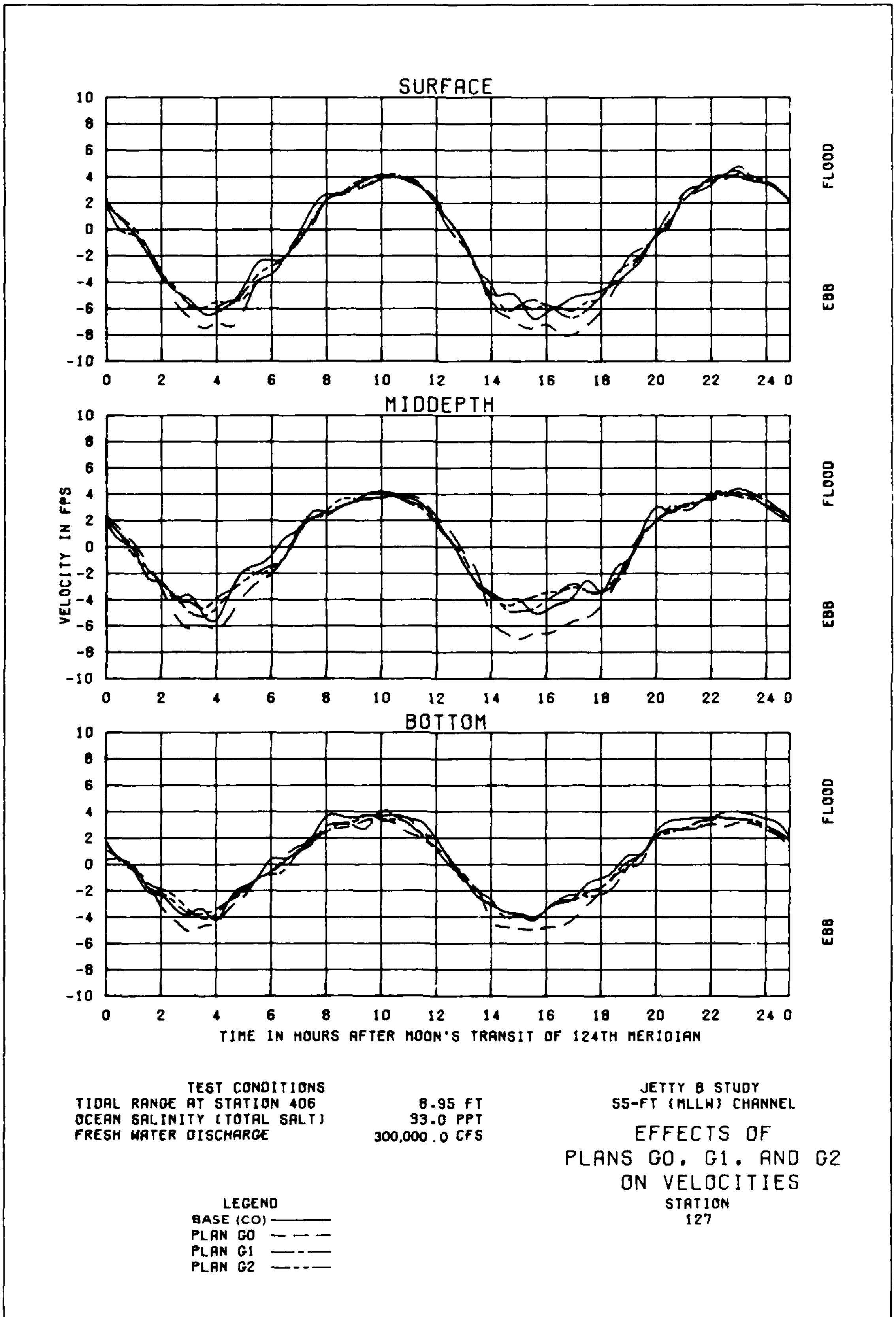
TIDAL RANGE AT STATION 406	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

LEGEND

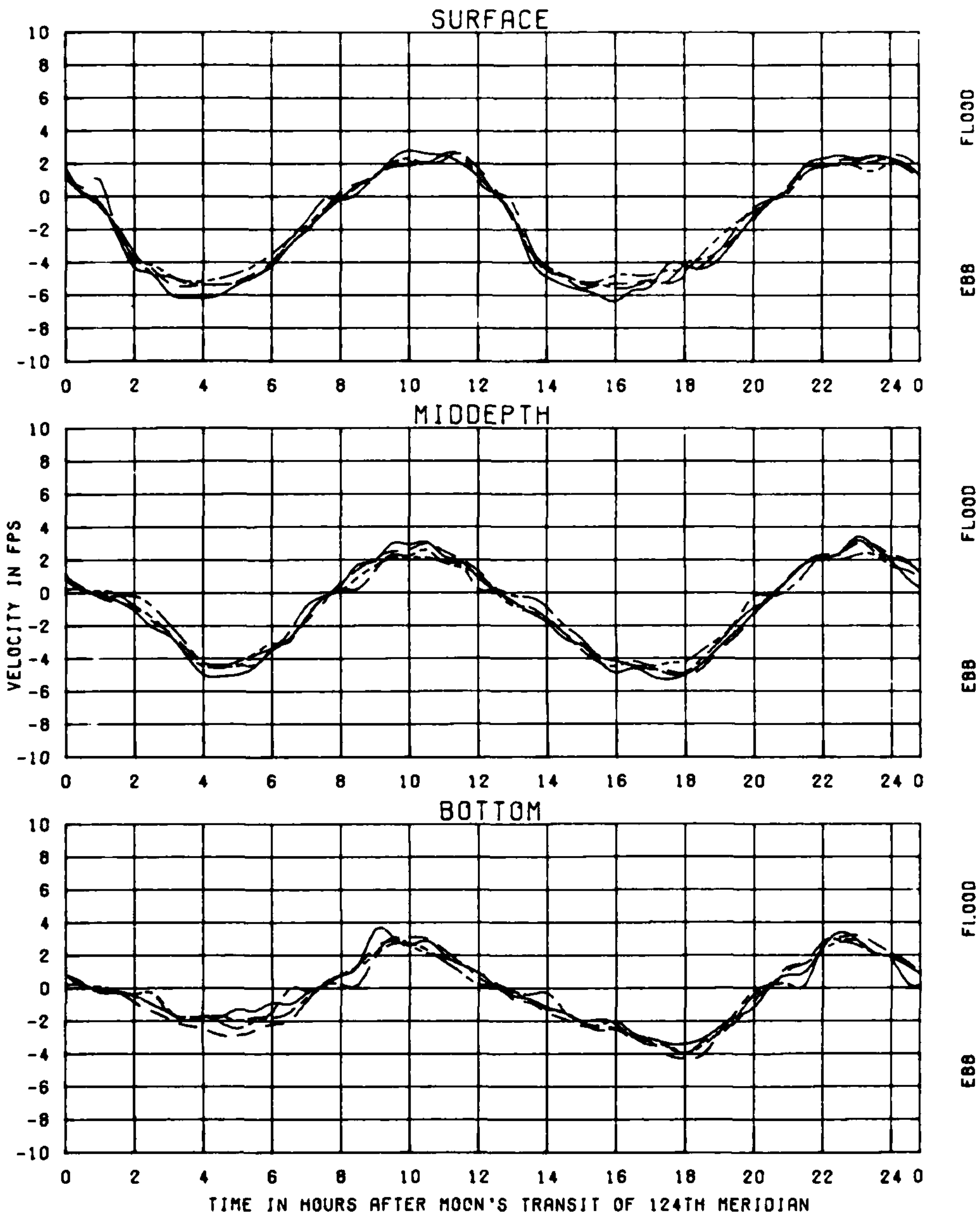
BASE (CO) ————
PLAN GO — — —
PLAN G1 —-—-—
PLAN G2 —--—

JETTY B STUDY
55-FT (MLLW) CHANNEL

EFFECTS OF
PLANS GO, G1, AND G2
ON TIDAL HEIGHTS
STATIONS
54, 392, AND 849



SURFACE
MIDDEPTH
BOTTOM
VELOCITY IN FPS
FLOOD
EBB
TIME IN HOURS AFTER MOON'S TRANSIT OF 124TH MERIDIAN
TEST CONDITIONS
TIDAL RANGE AT STATION 406 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESH WATER DISCHARGE 300,000.0 CFS
JETTY B STUDY
55-FT (MLLW) CHANNEL
EFFECTS OF
PLANS G0, G1, AND G2
ON VELOCITIES
STATION
127
LEGEND
BASE (C0)
PLAN G0
PLAN G1
PLAN G2



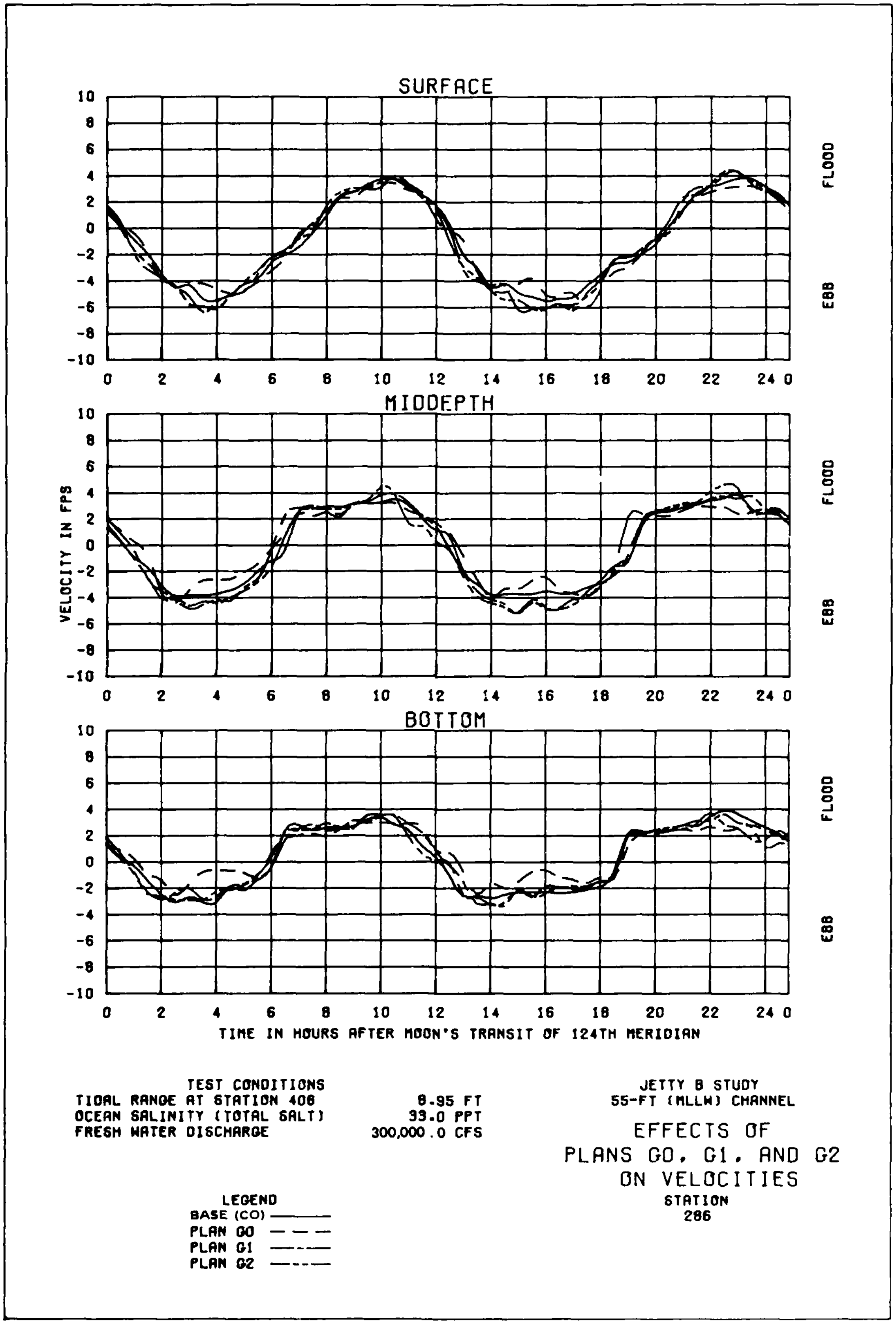
TEST CONDITIONS

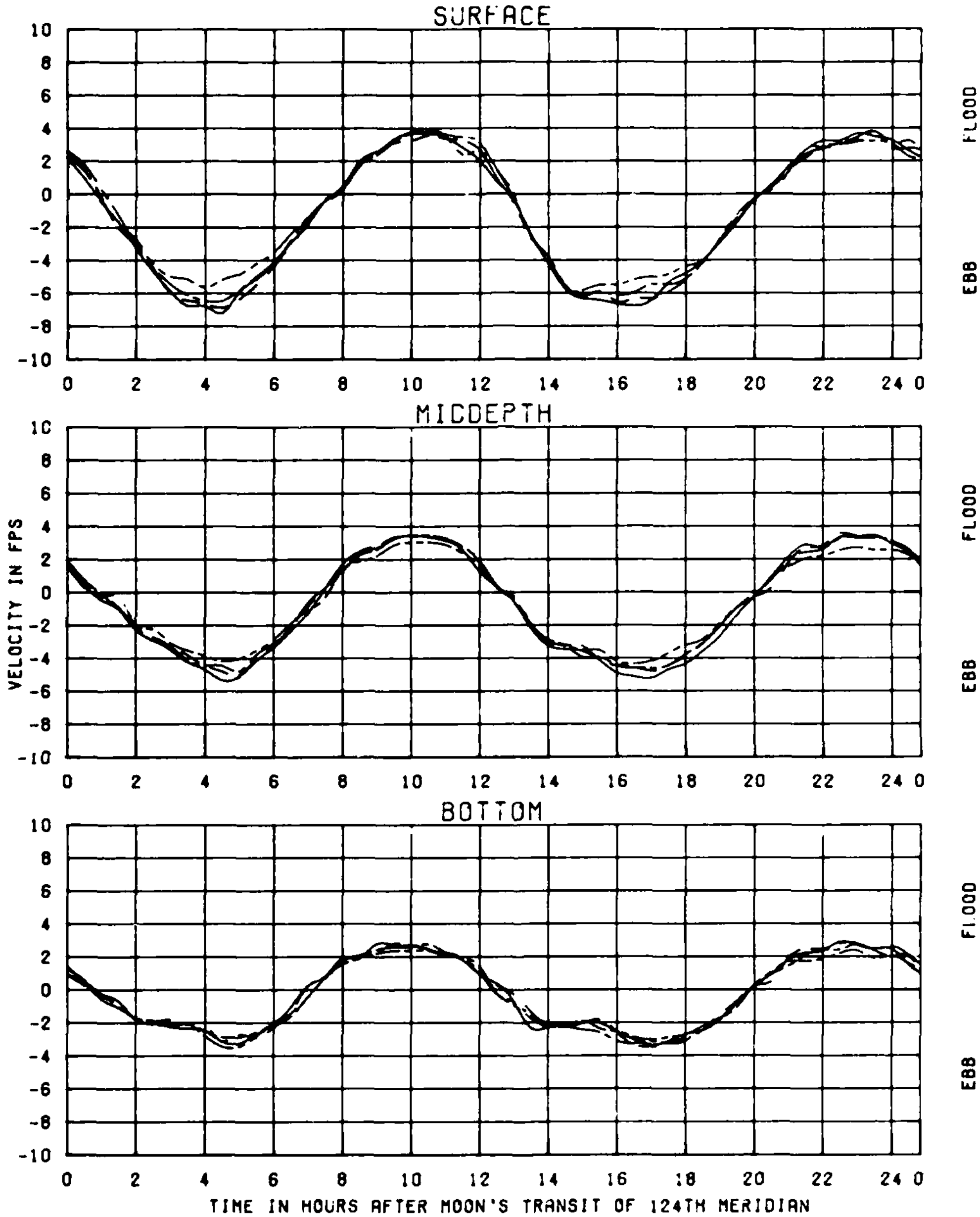
TIDAL RANGE AT STATION 406	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

JETTY B STUDY
55-FT (MLLW) CHANNEL

EFFECTS OF
PLANS G0, G1, AND G2
ON VELOCITIES
STATION
160

LEGEND
BASE (C0) ————
PLAN G0 — — —
PLAN G1 ——---
PLAN G2 ——----


SURFACE
MIDDEPTH
BOTTOM
VELOCITY IN FPS
FLOOD
EBB
TIME IN HOURS AFTER MOON'S TRANSIT OF 124TH MERIDIAN
TEST CONDITIONS
TIDAL RANGE AT STATION 406 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESH WATER DISCHARGE 300,000.0 CFS
JETTY B STUDY
55-FT (MLLW) CHANNEL
EFFECTS OF
PLANS G0, G1, AND G2
ON VELOCITIES
STATION
286
LEGEND
BASE (C0)
PLAN G0
PLAN G1
PLAN G2



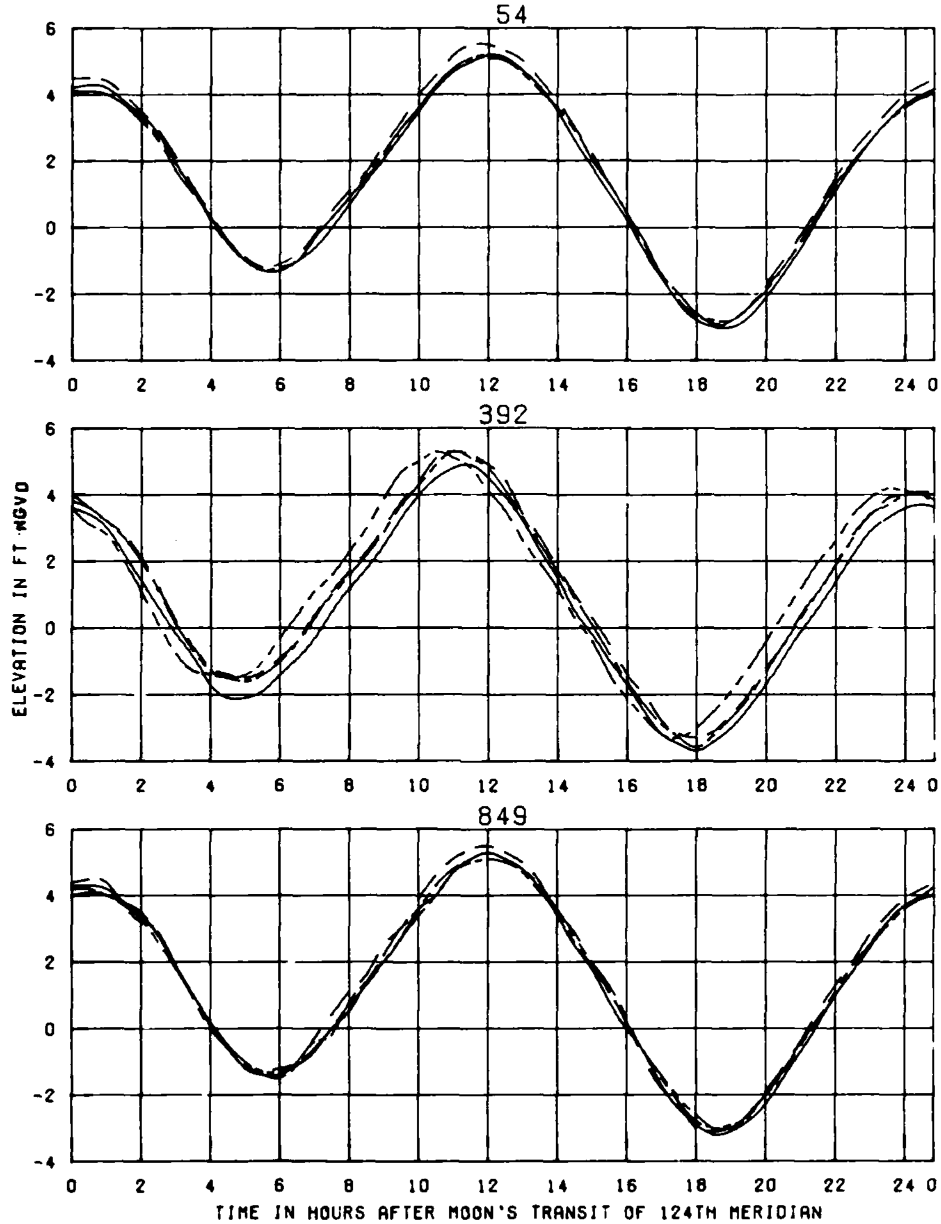
TEST CONDITIONS

TIDAL RANGE AT STATION 406	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

LEGEND
BASE (CO) ———
PLAN GO — — —
PLAN G1 —·—·—
PLAN G2 -------

JETTY B STUDY
55-FT (MLLW) CHANNEL

EFFECTS OF
PLANS GO, G1, AND G2
ON VELOCITIES
STATION
823



TEST CONDITIONS

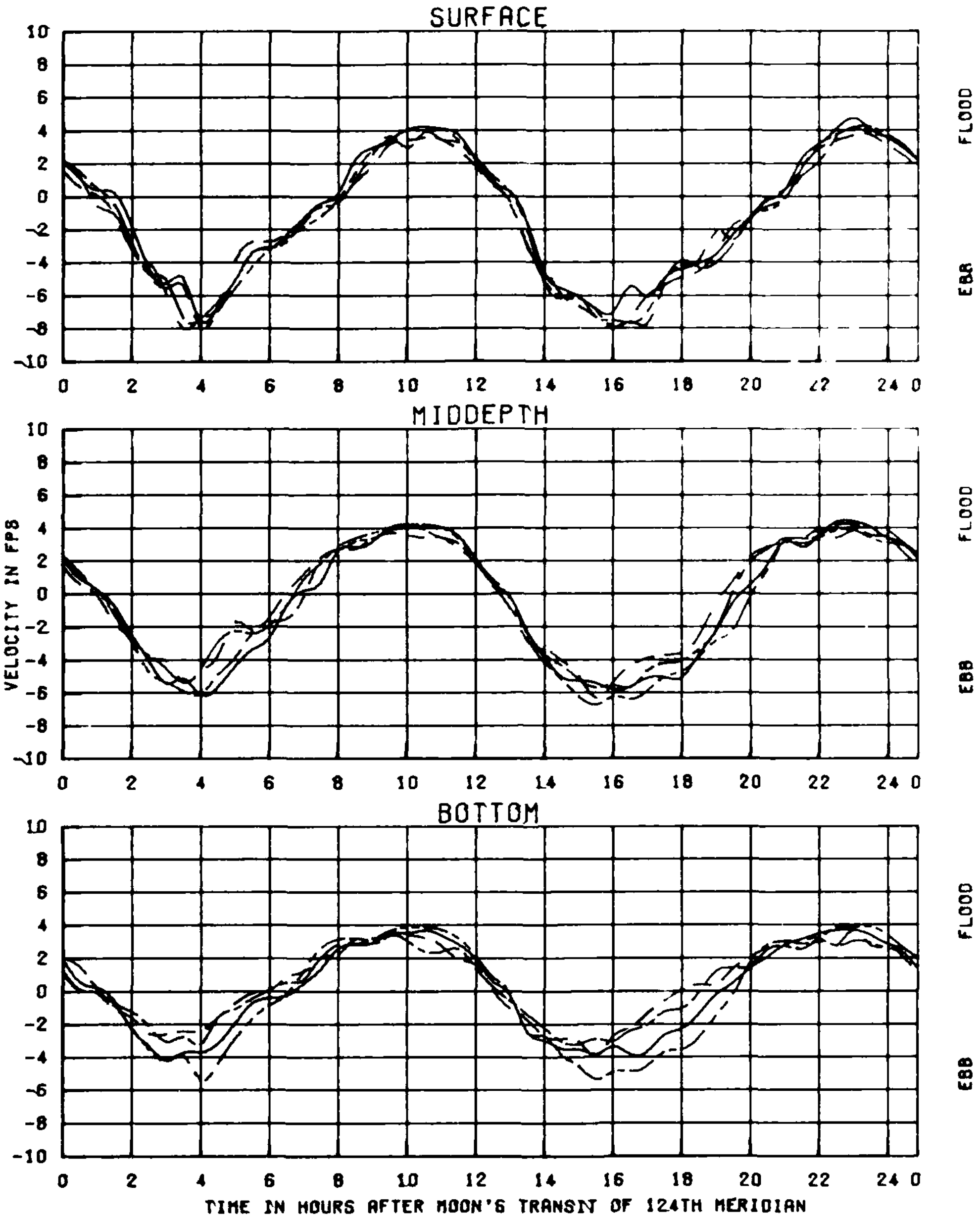
TIDAL RANGE AT STATION 406 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESH WATER DISCHARGE 300,000.0 CFS

LEGEND
BASE
PLAN H0
PLAN H1
PLAN I0

60-FT MLLW CHANNEL STUDY
55-FT MLLW CHANNEL REALIGNMENT

EFFECTS OF
PLANS H0, H1, AND I0
ON TIDAL HEIGHTS

STATIONS
54, 392, AND 849



TEST CONDITIONS

TIDAL RANGE AT STATION 406	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

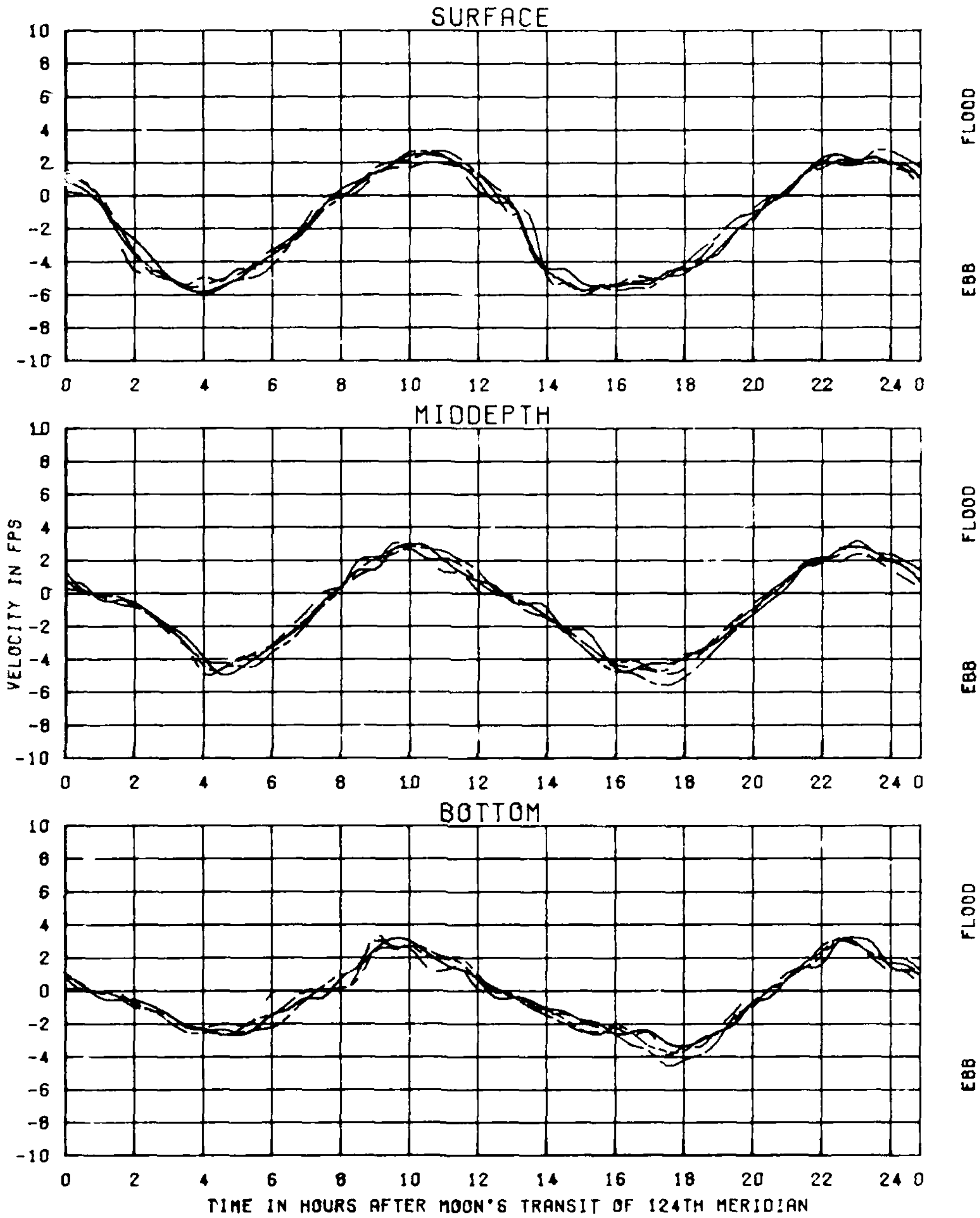
LEGEND

BASE ————
PLAN HO — — —
PLAN H1 —·—·—
PLAN IO —··—··

60-FT MLLW CHANNEL STUDY
55-FT MLLW CHANNEL REALIGNMENT

EFFECTS OF
PLANS HO, H1, AND IO
ON VELOCITIES

STATION
127



TEST CONDITIONS

TIDAL RANGE AT STATION 406	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

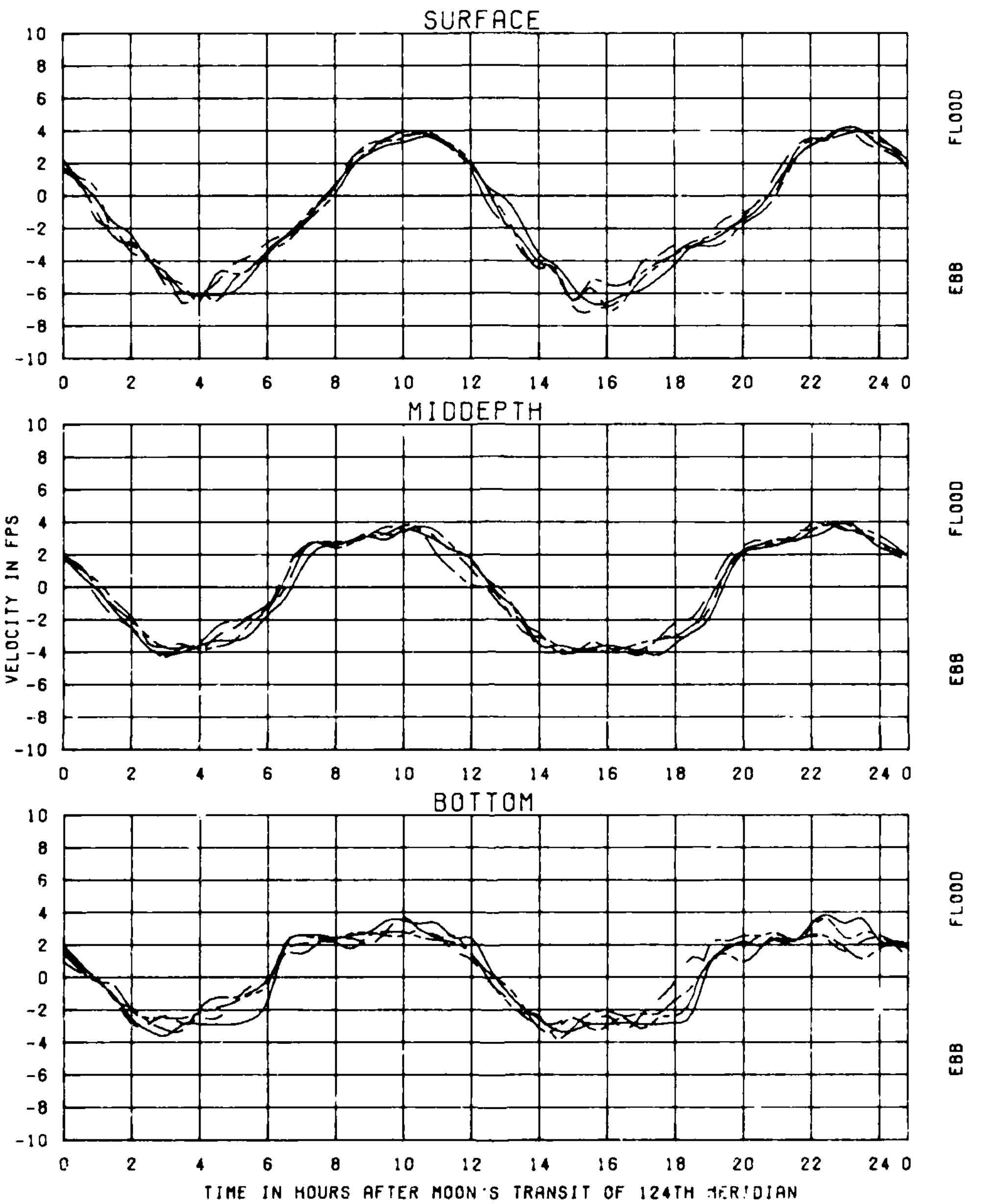
LEGEND

BASE
PLAN H0
PLAN H1
PLAN I0

60-FT MLLW CHANNEL STUDY
55-FT MLLW CHANNEL REALIGNMENT

EFFECTS OF
PLANS H0, H1, AND I0
ON VELOCITIES

STATION
160

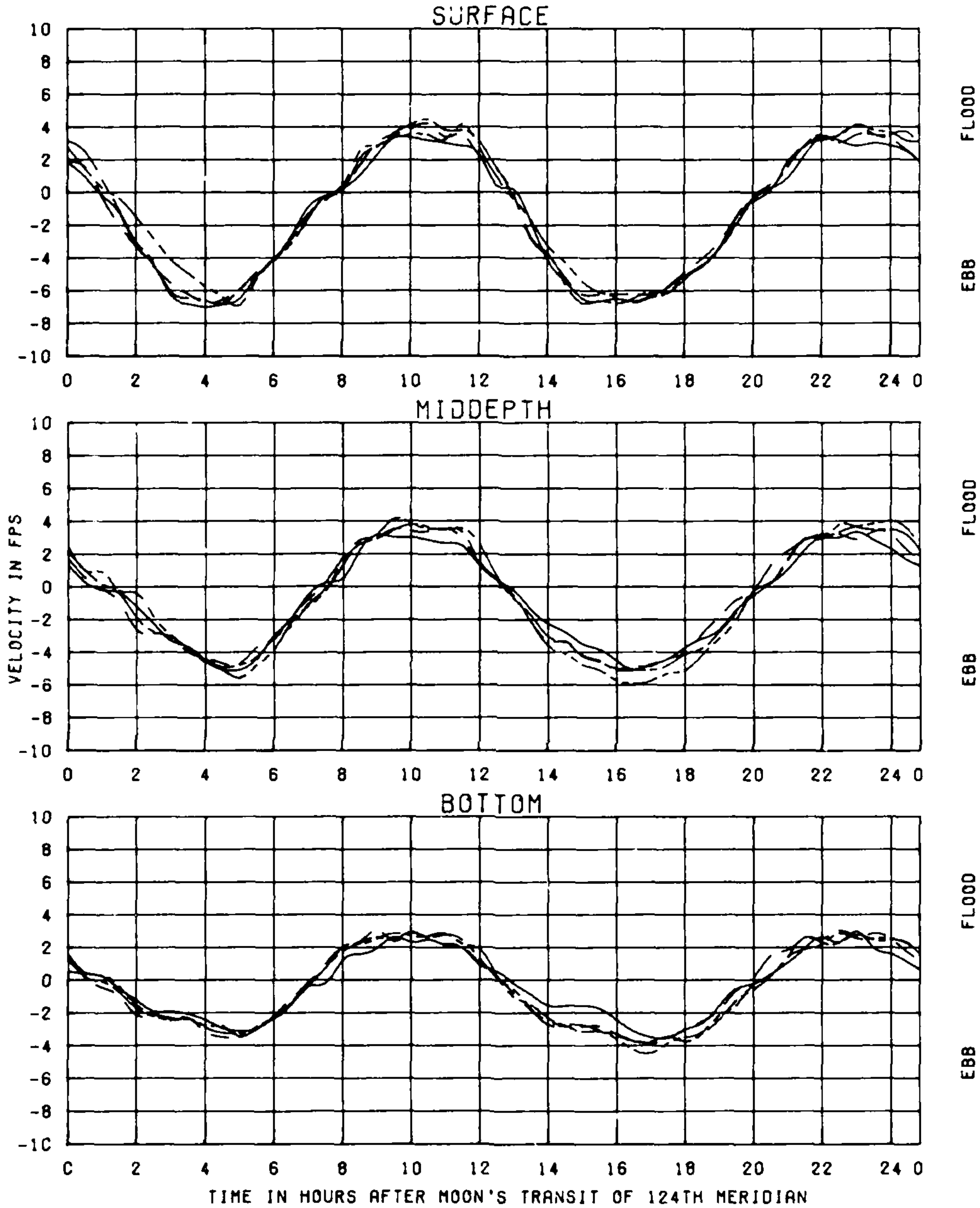


TEST CONDITIONS	
TIDAL RANGE AT STATION 406	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

60-FT MLLW CHANNEL STUDY
55-FT MLLW CHANNEL REALIGNMENT

EFFECTS OF
PLANS HO, H1, AND IO
ON VELOCITIES
STATION
286

LEGEND
BASE ————
PLAN HO — — —
PLAN H1 —-—
PLAN IO —--—



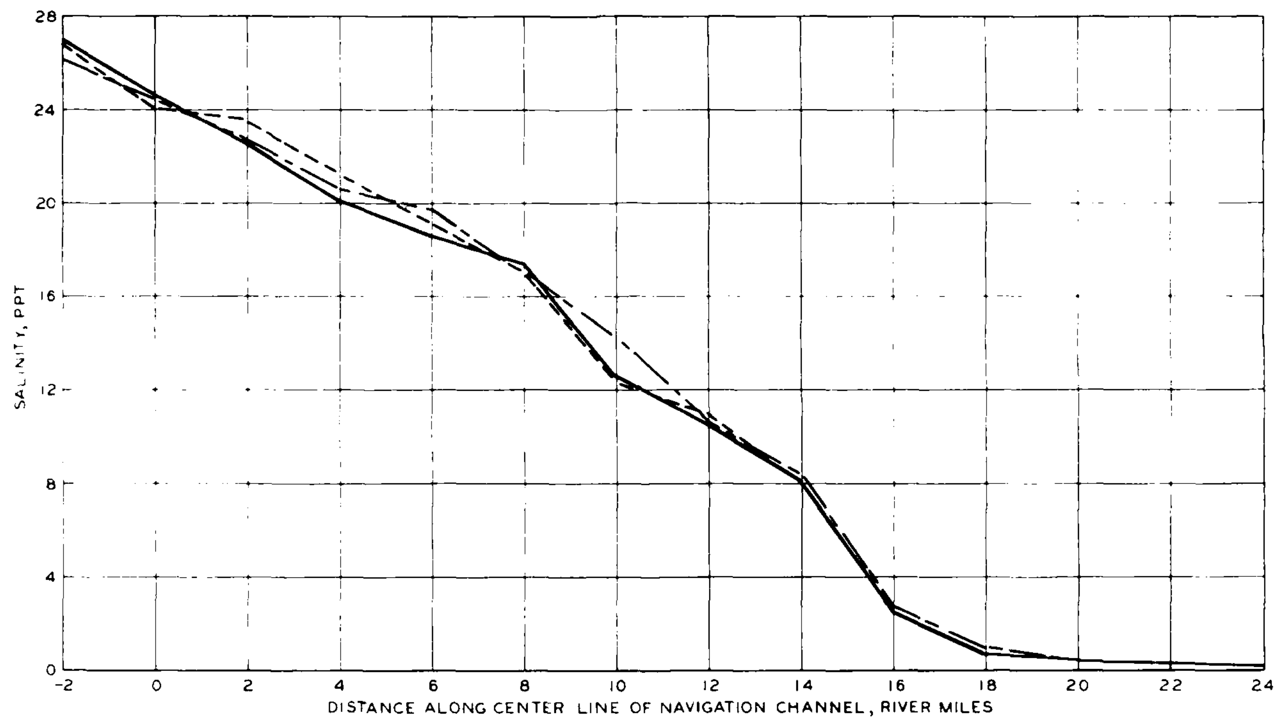
TEST CONDITIONS	
TIDAL RANGE AT STATION 406	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESH WATER DISCHARGE	300,000.0 CFS

60-FT MLLW CHANNEL STUDY
55-FT MLLW CHANNEL REALIGNMENT

EFFECTS OF
PLANS H0, H1, AND I0
ON VELOCITIES
STATION
823

LEGEND
BASE ————
PLAN H0 — — —
PLAN H1 —·—·—
PLAN I0 —·····—

PLATE 34



TEST CONDITIONS

TIDE RANGE AT STATION 406 (PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

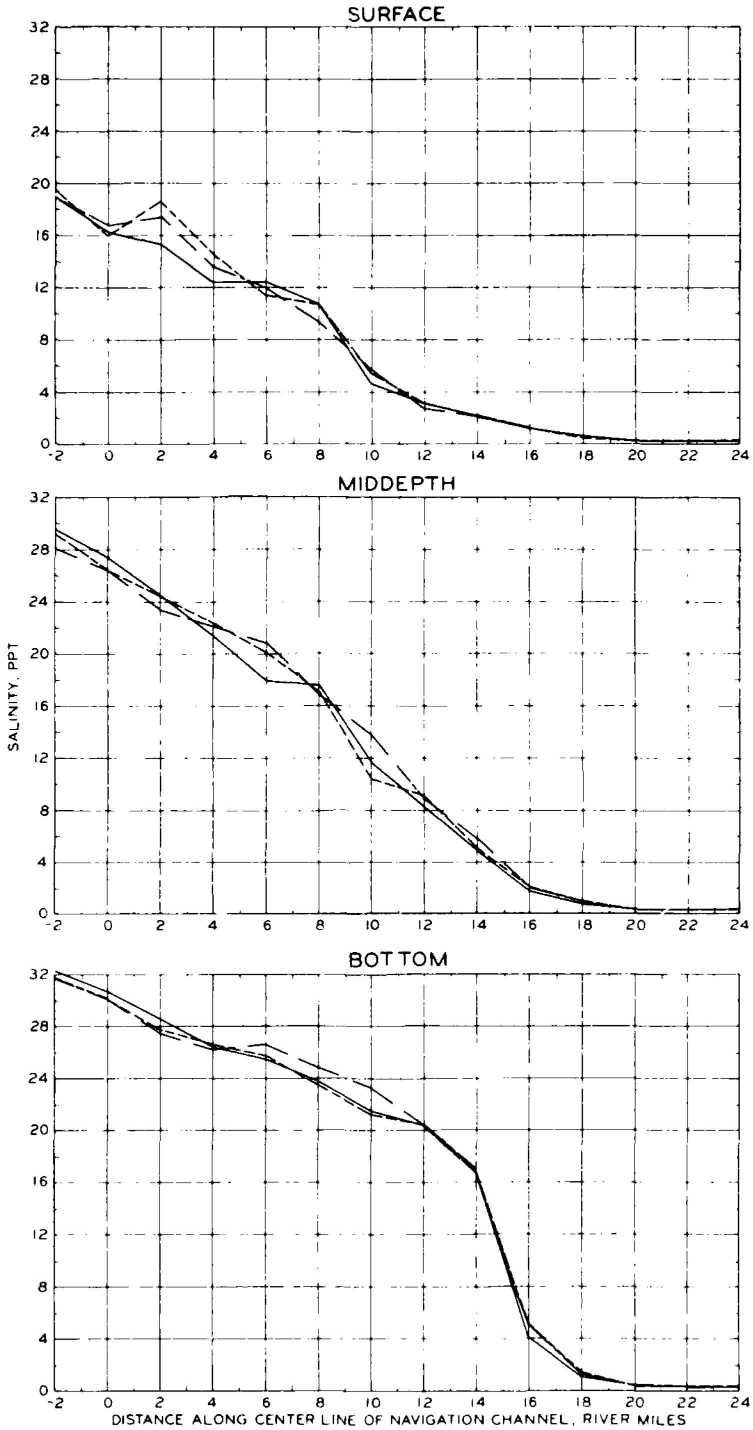
LEGEND

BASE (AO)
AUTHORIZED (A1)
DEGRADED (A2)

NORTH JETTY STUDY

AVERAGE SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: AVERAGE OF SURFACE, MIDDEPTH, AND BOTTOM



TEST CONDITIONS

TIDE RANGE AT STA 406 (PIT)	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESHWATER DISCHARGE	140,000 CFS

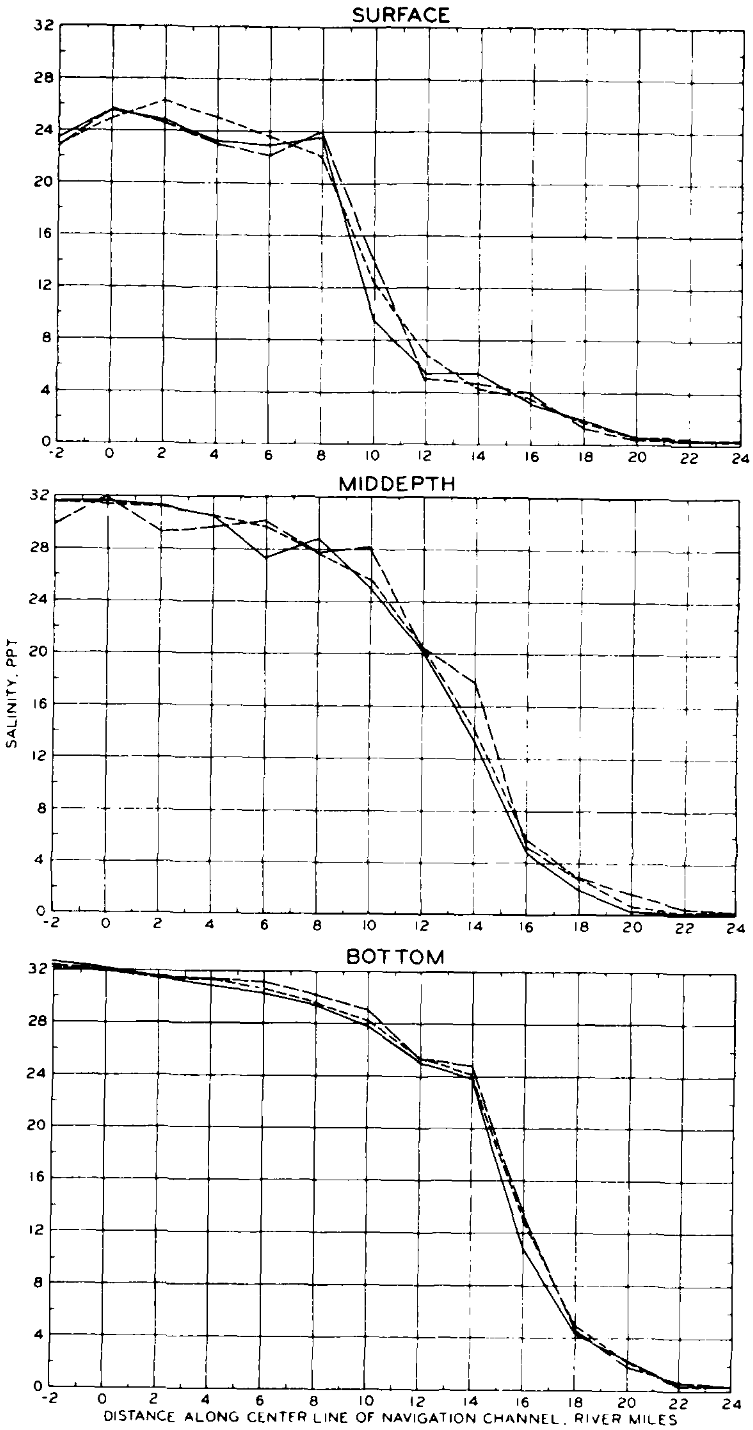
LEGEND

- BASE (A0)
- AUTHORIZED (A1)
- DEGRADED (A2)

NORTH JETTY STUDY

AVERAGE SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM



TEST CONDITIONS

TIDE RANGE AT STA 406 (PIT)	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESHWATER DISCHARGE	140,000 CFS

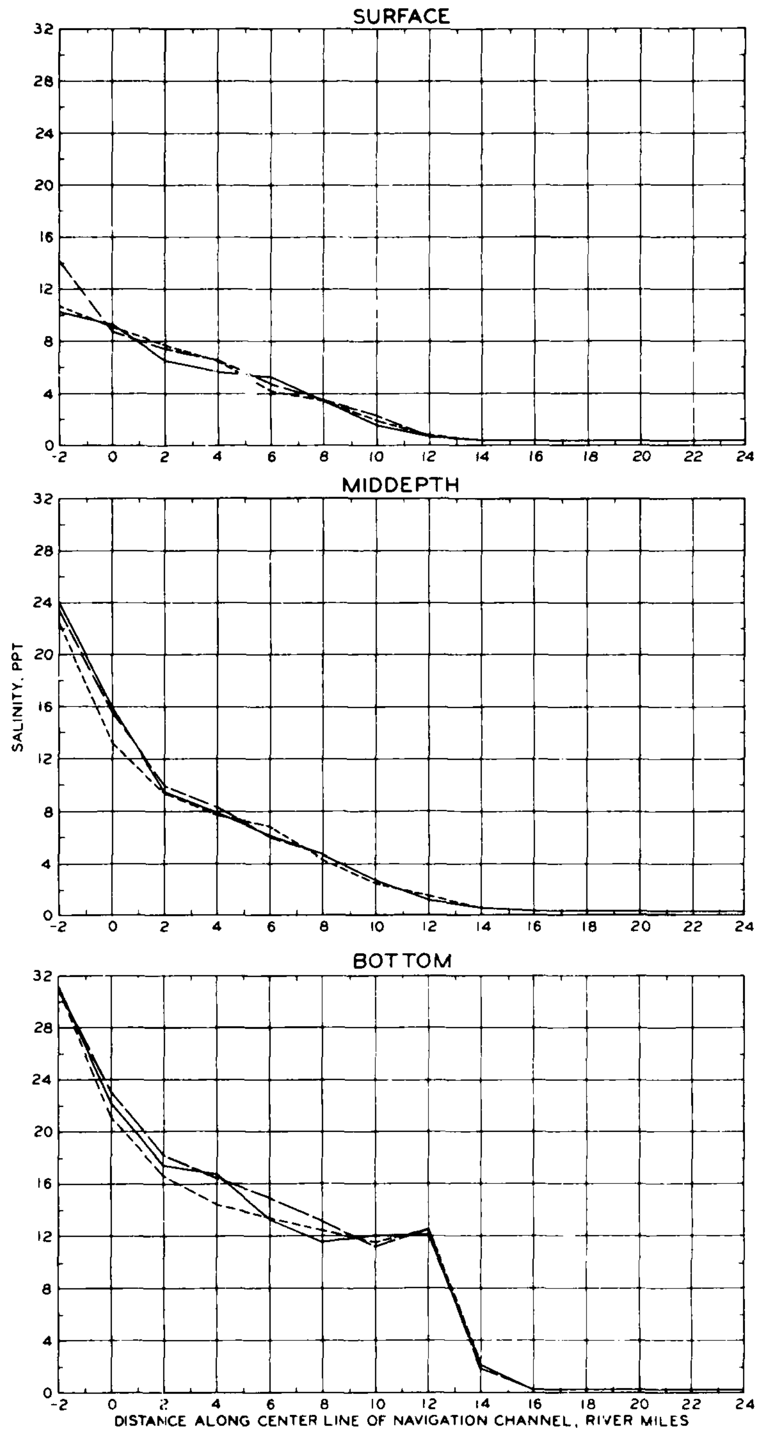
LEGEND

- ——— BASE (A0)
- - - - - - AUTHORIZED (A1)
- — — DEGRADED (A2)

NORTH JETTY STUDY

MAXIMUM SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM



TEST CONDITIONS

TIDE RANGE AT STA 406 (PIT)	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESHWATER DISCHARGE	140,000 CFS

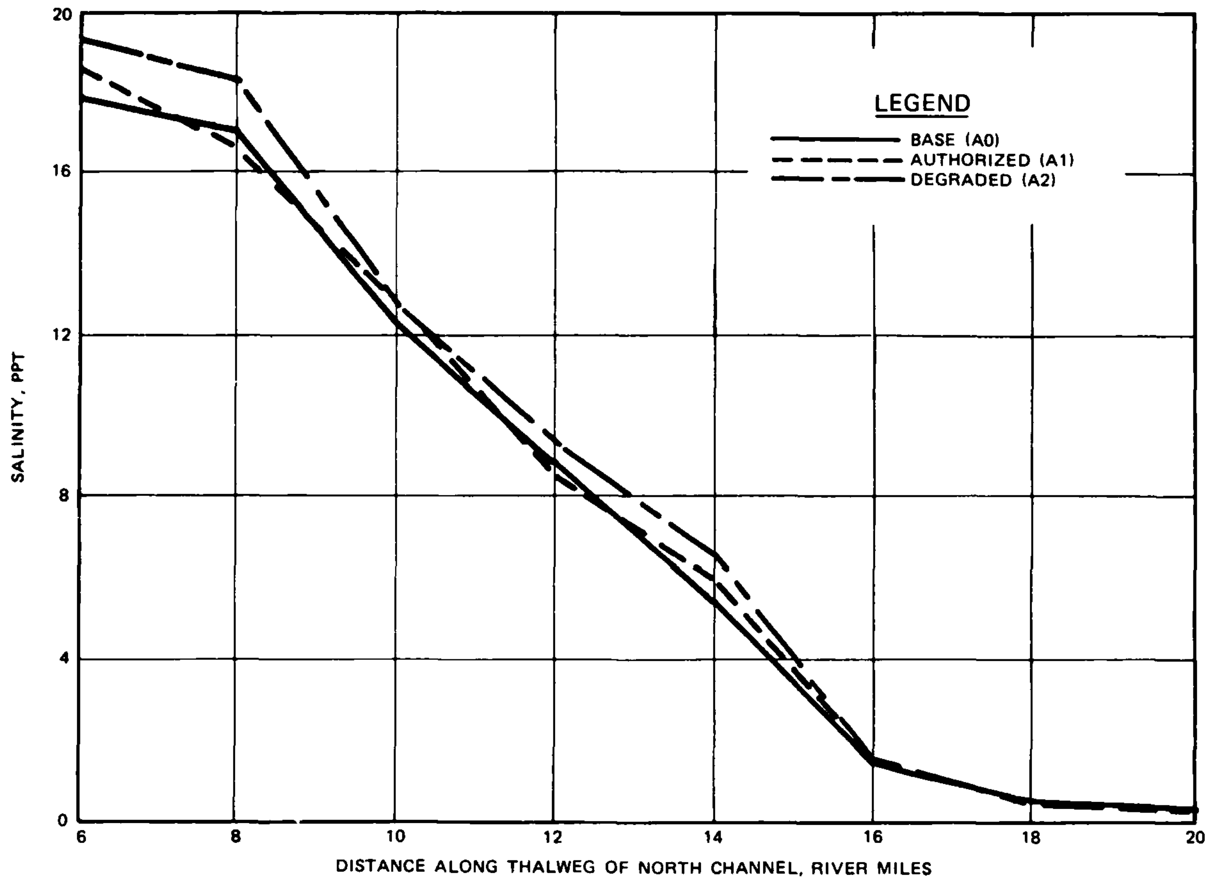
LEGEND

——— BASE (A0)
- - - - AUTHORIZED (A1)
— — — DEGRADED (A2)

NORTH JETTY STUDY

MINIMUM SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM



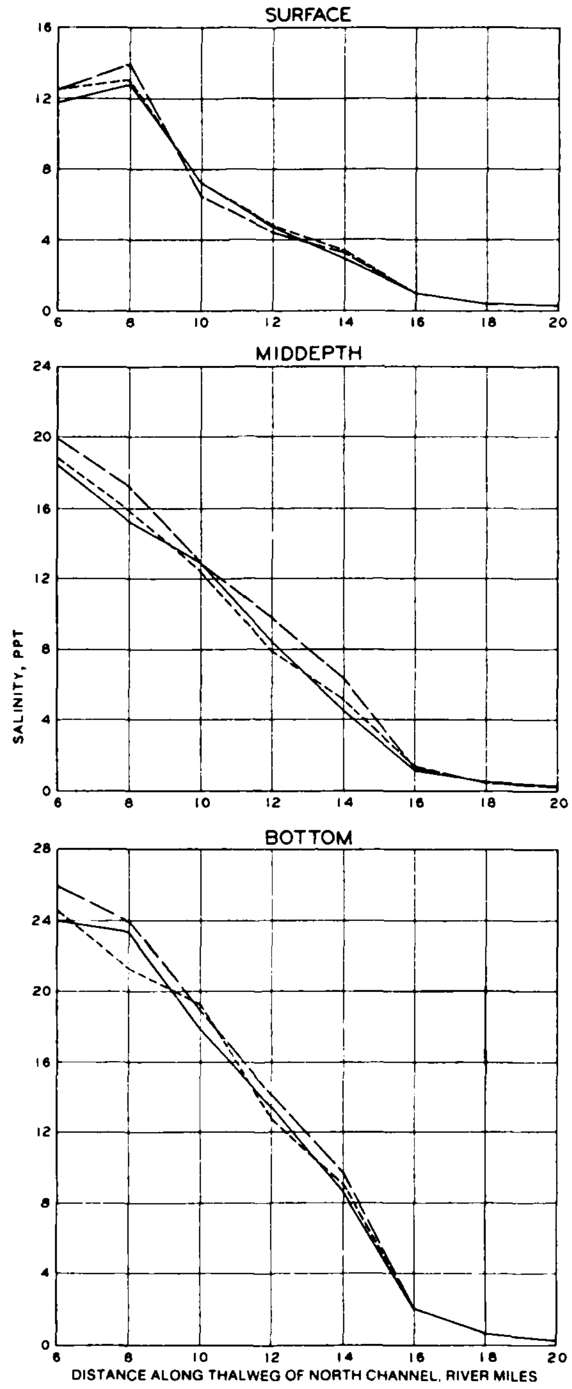
TEST CONDITION

TIDE RANGE AT STATION 406 (PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

NORTH JETTY STUDY

AVERAGE SALINITY PROFILE ALONG
THALWEG OF NORTH CHANNEL

DEPTH: AVERAGE OF SURFACE, MIDDEPTH,
AND BOTTOM



TEST CONDITIONS

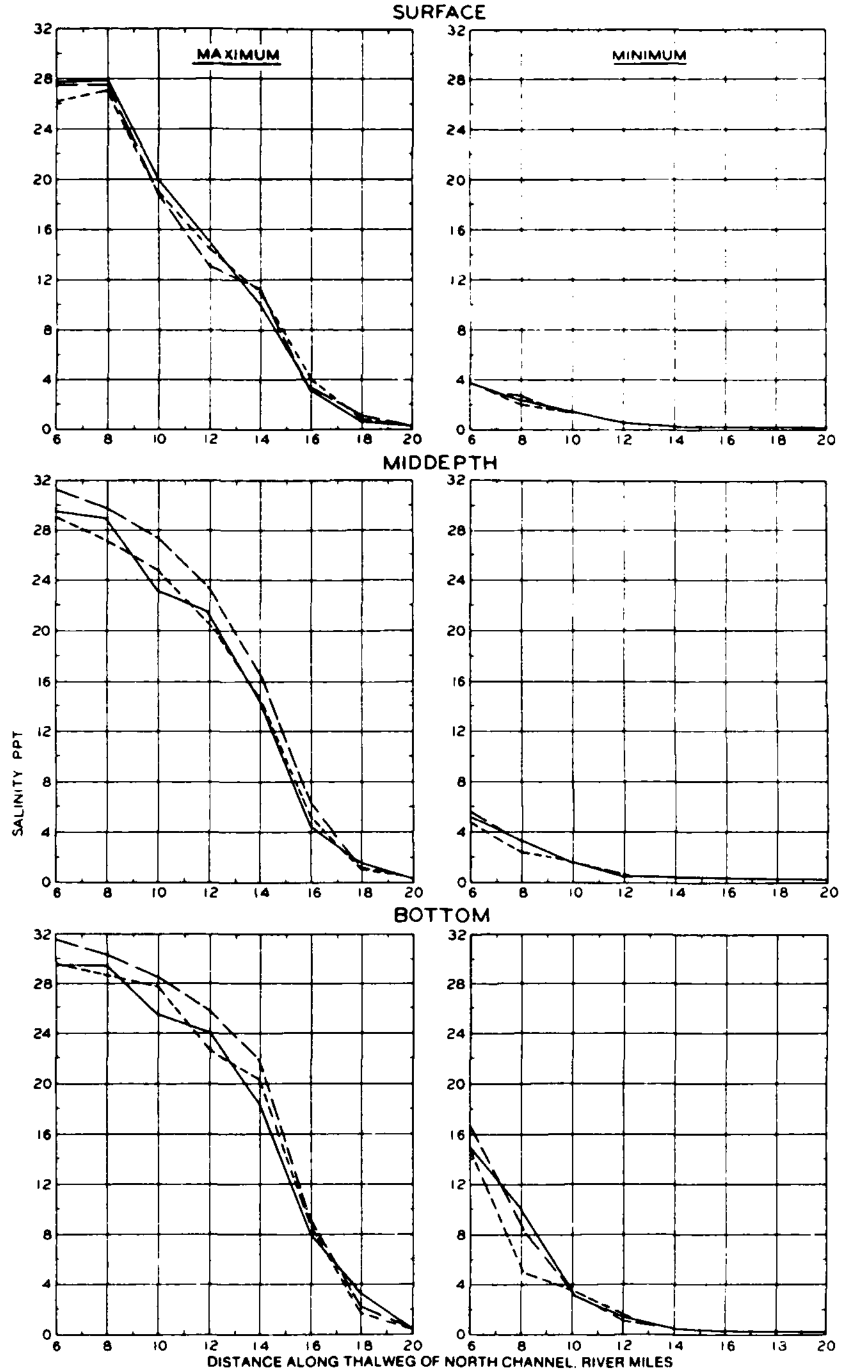
TIDE RANGE AT STATION 406 (PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

LEGEND

——— BASE (A0)
- - - - AUTHORIZED (A1)
— — — DEGRADED (A2)

NORTH JETTY STUDY

AVERAGE SALINITY PROFILES ALONG THALWEG OF NORTH CHANNEL



TEST CONDITIONS

TIDE RANGE AT STA 406 (PIT)	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESHWATER DISCHARGE	140,000 CFS

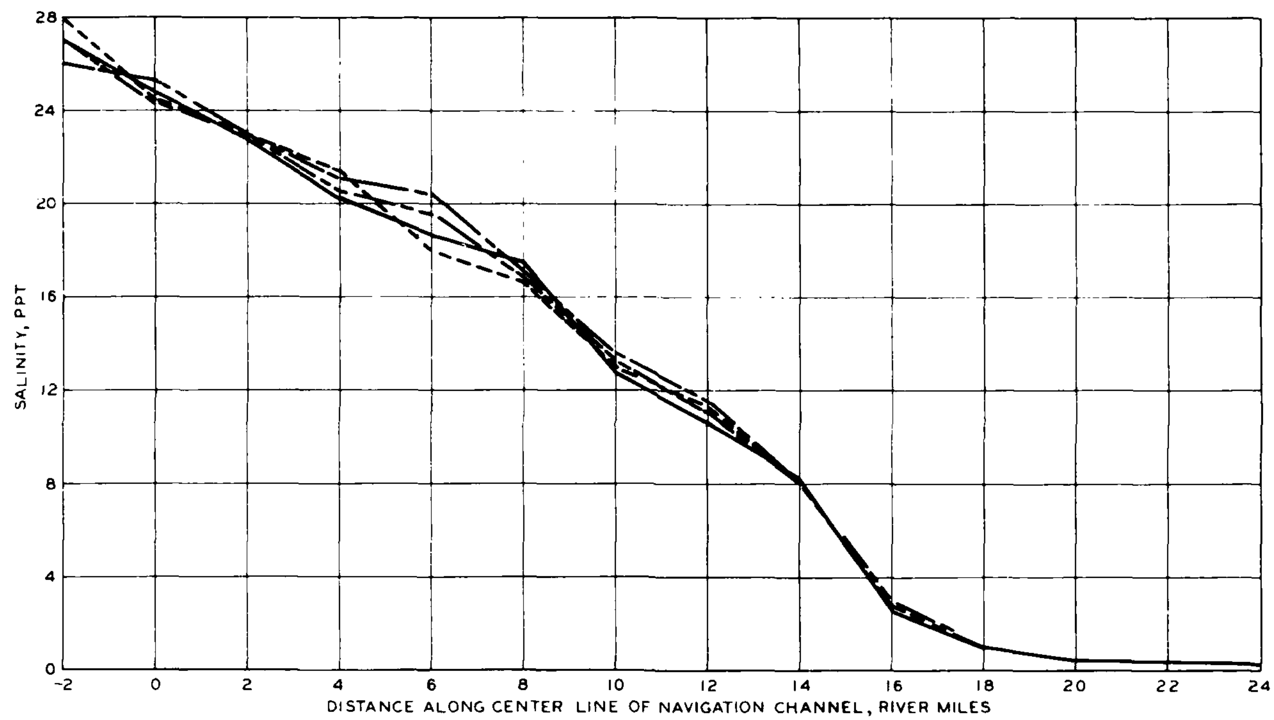
LEGEND

——— BASE (A0)
- - - - AUTHORIZED (A1)
— — — DEGRADED (A2)

NORTH JETTY STUDY

MAXIMUM AND MINIMUM SALINITY PROFILE ALONG THALWEG OF NORTH CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM



TEST CONDITIONS

TIDE RANGE AT STATION 406 (PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

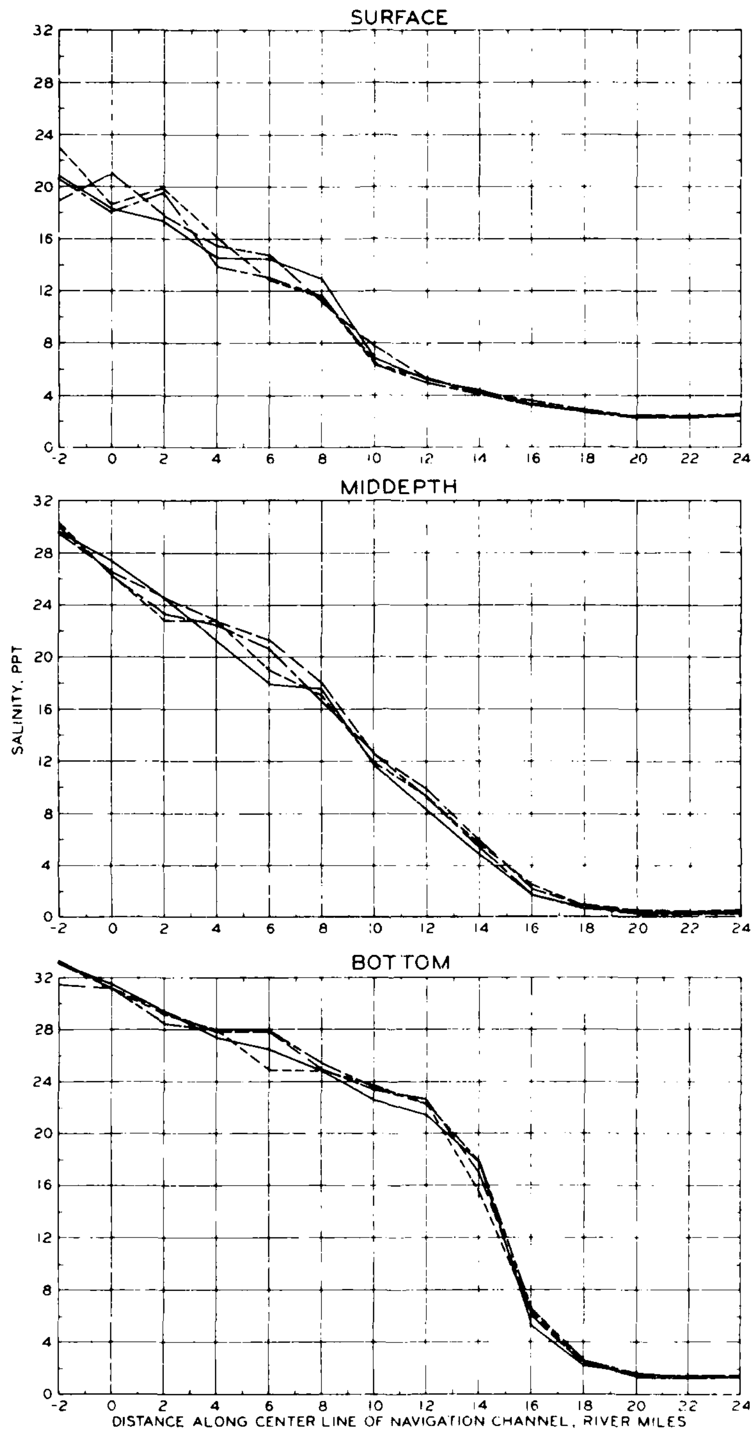
LEGEND

BASE (A0)
AUTHORIZED (B1)
DEGRADED (B2)
REHAB (B3)

SOUTH JETTY STUDY

AVERAGE SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: AVERAGE OF SURFACE, MIDDEPTH, AND BOTTOM



TEST CONDITIONS

TIDE RANGE AT STA 406 (PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

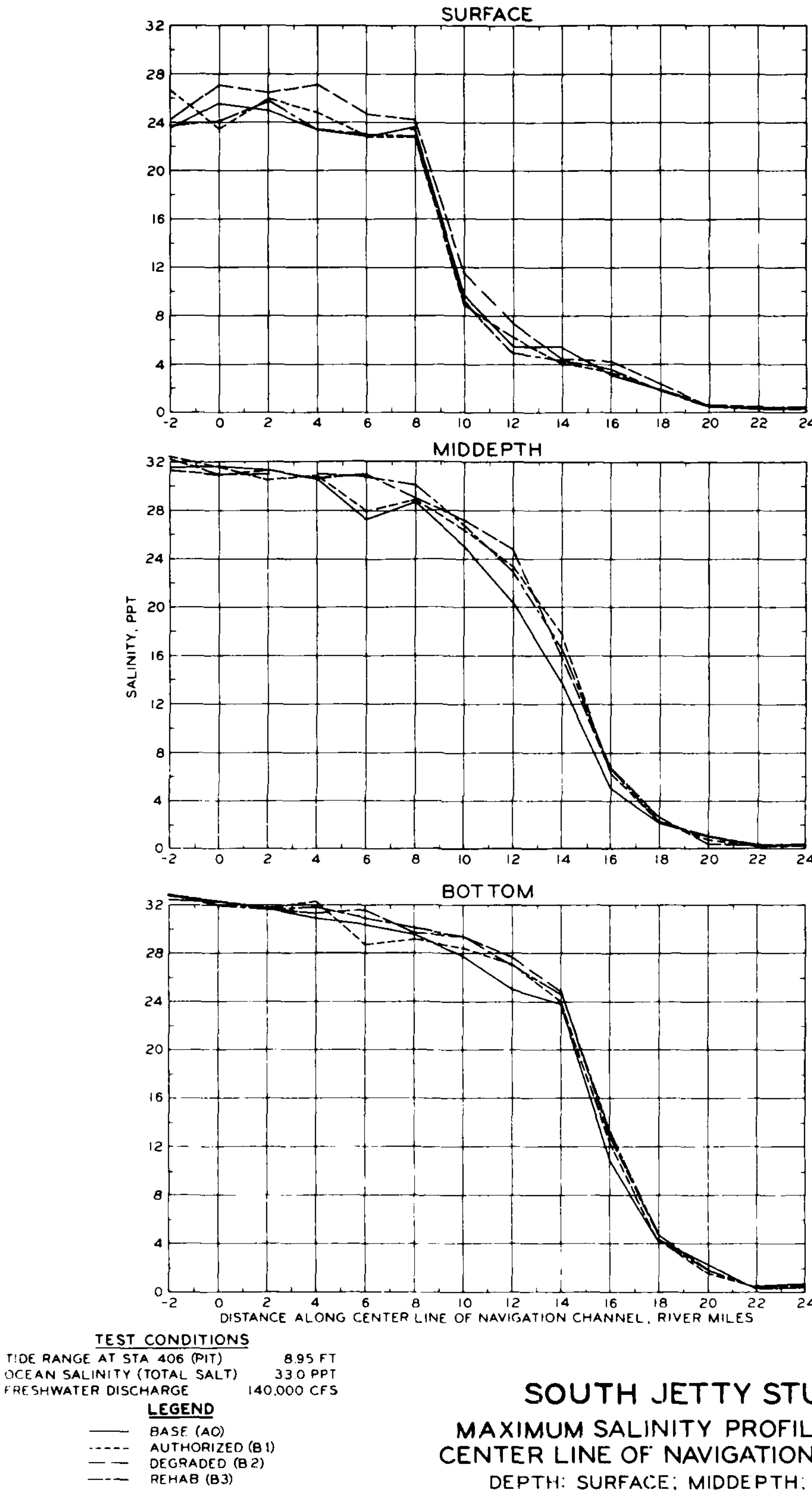
LEGEND

BASE (A0)
AUTHORIZED (B1)
DEGRADED (B2)
REHAB (B3)

SOUTH JETTY STUDY

AVERAGE SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

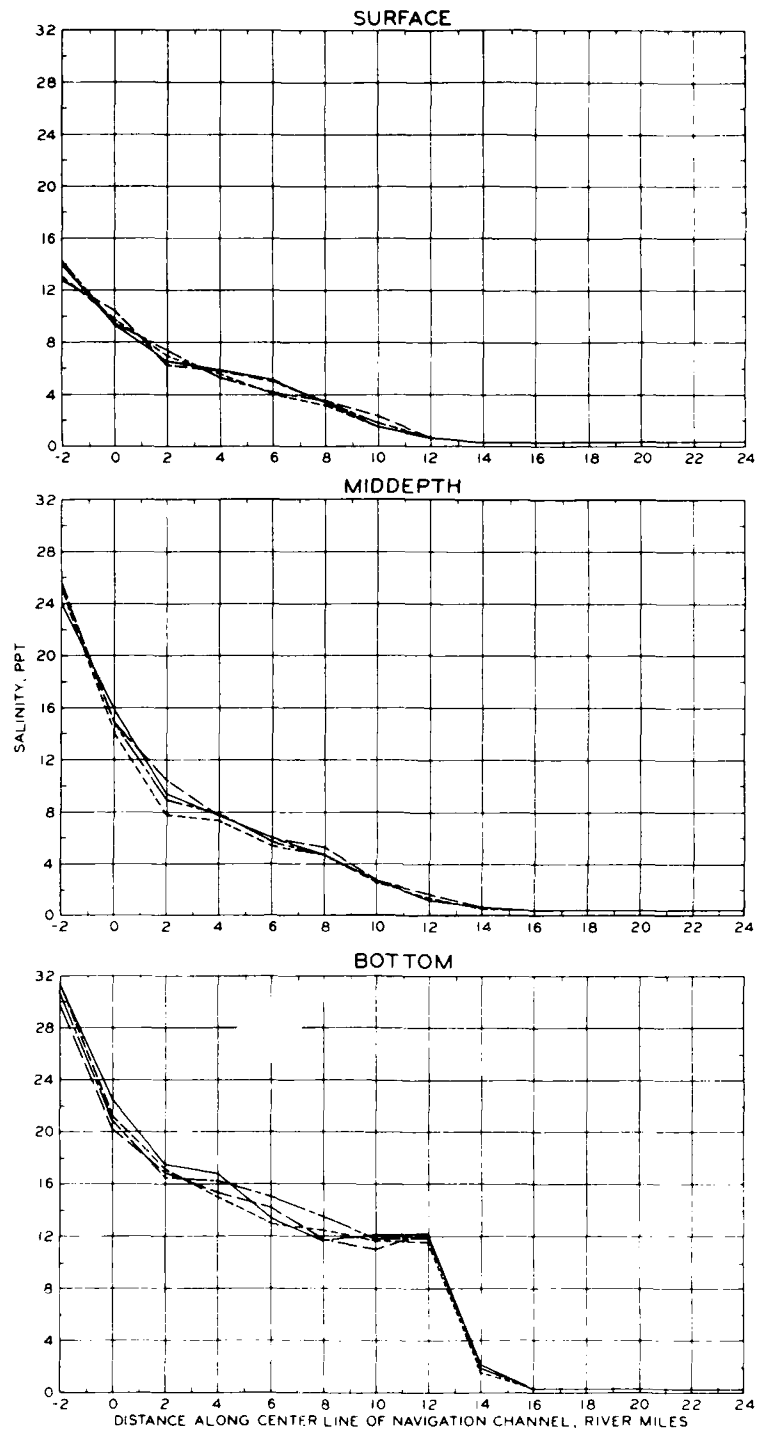
DEPTH: SURFACE; MIDDEPTH; BOTTOM



SOUTH JETTY STUDY

MAXIMUM SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM



TEST CONDITIONS

TIDE RANGE AT STA 406 (PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

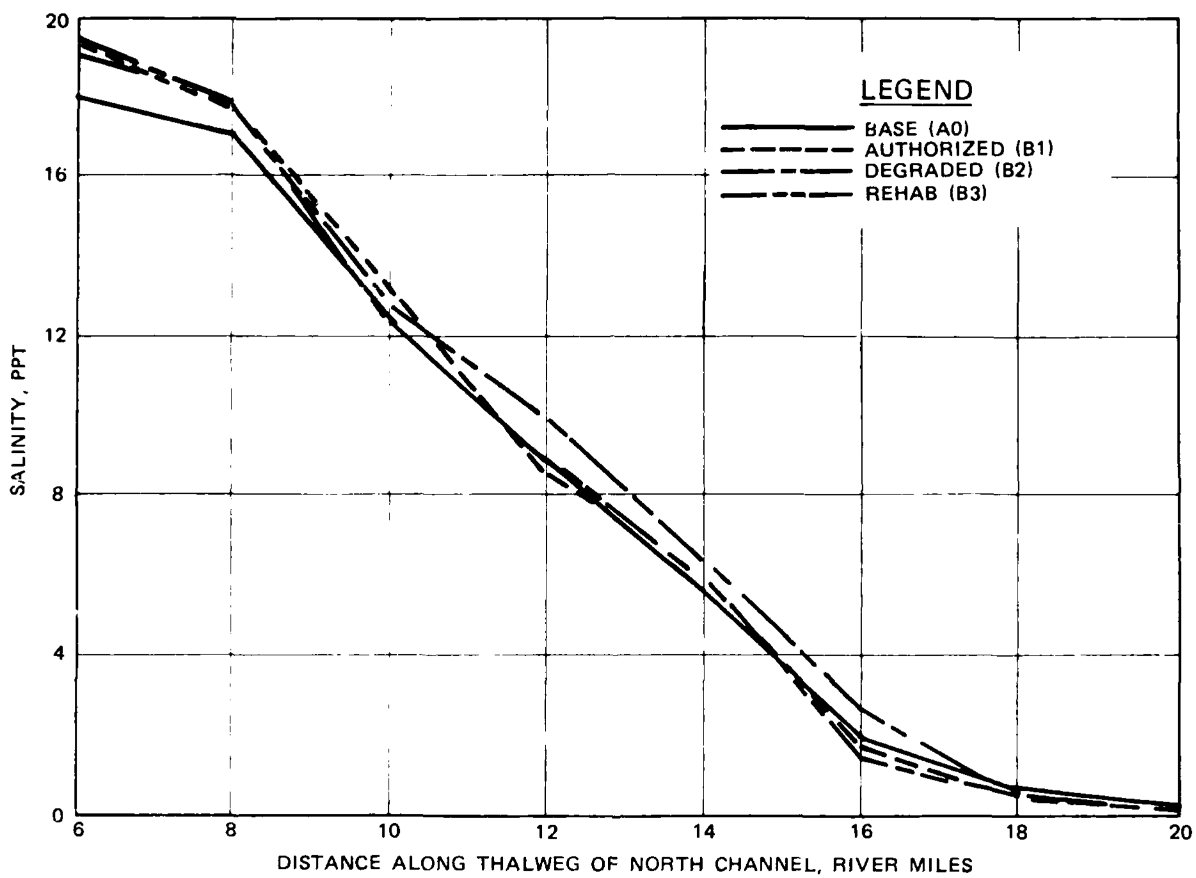
LEGEND

BASE (AO)
AUTHORIZED (B1)
DEGRADED (B2)
REHAB (B3)

SOUTH JETTY STUDY

MINIMUM SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM



TEST CONDITION

TIDE RANGE AT STATION 406 (PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

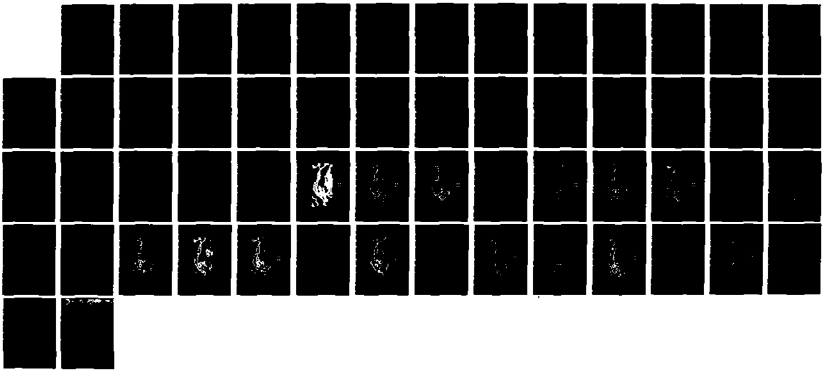
SOUTH JETTY STUDY

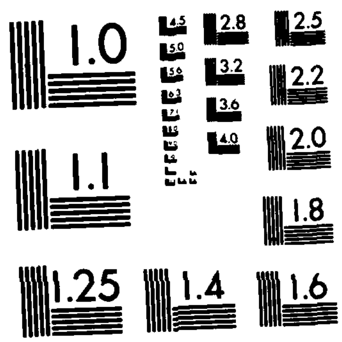
AVERAGE SALINITY PROFILE ALONG THALWEG OF NORTH CHANNEL

DEPTH: AVERAGE OF SURFACE, MIDDEPTH, AND BOTTOM

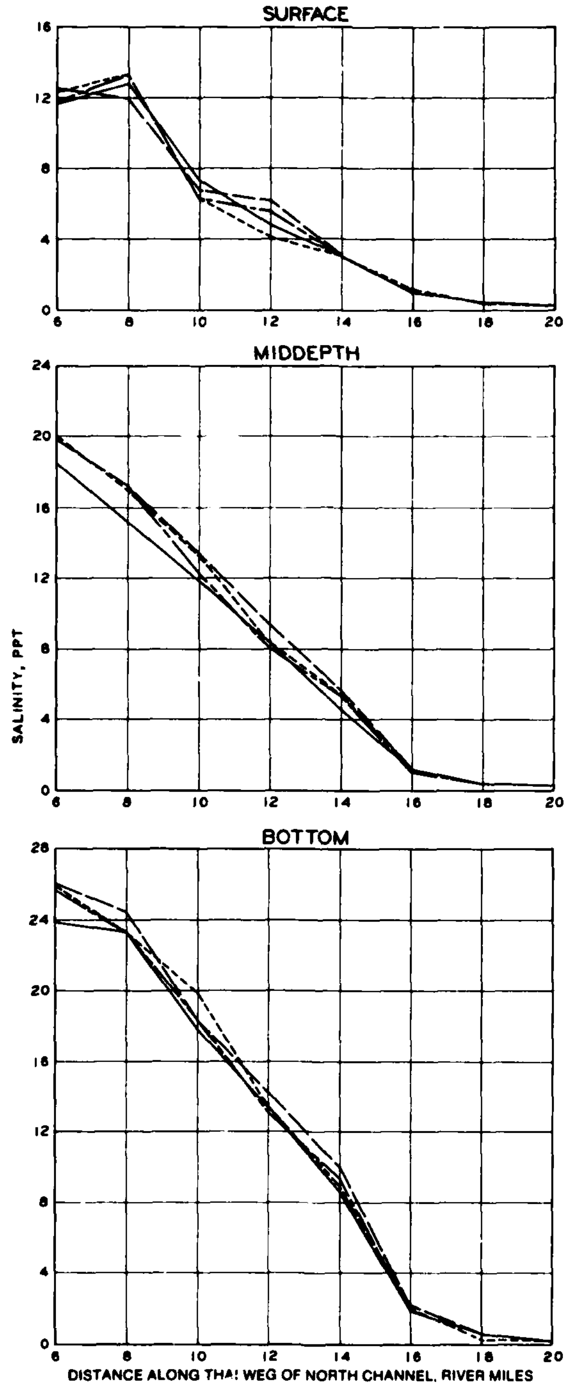
AD-A134 581 COLUMBIA RIVER ESTUARY HYBRID MODEL STUDIES REPORT 4 ENTRANCE CHANNEL TES..(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS HYDRA.. 2/2

UNCLASSIFIED W H MCANALLY ET AL. SEP 83 WES/TR/HL/83-16 F/G 13/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



TEST CONDITIONS

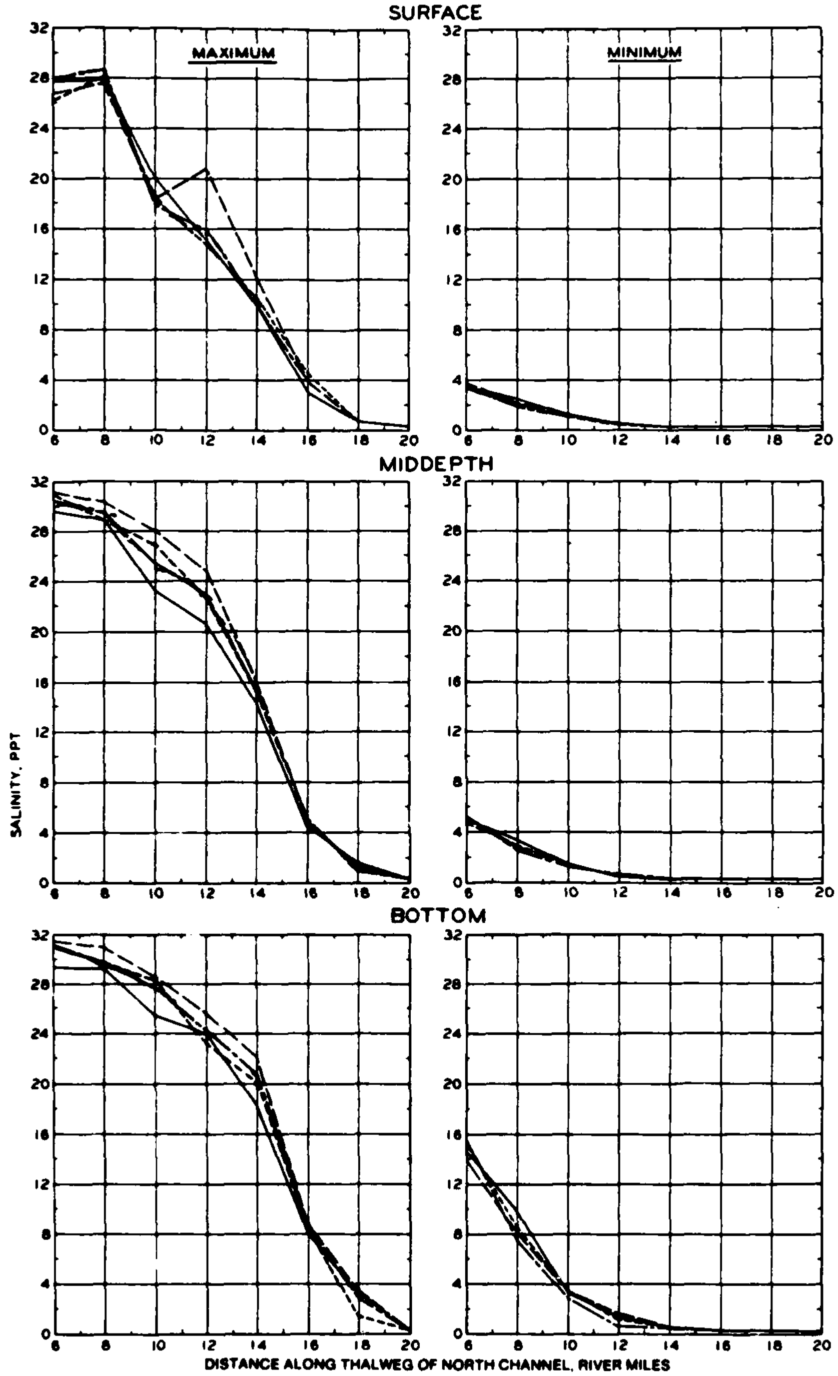
TIDE RANGE AT STATION 406(PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

LEGEND

BASE (A0)
AUTHORIZED (B1)
DEGRADED (B2)
REHAB. (B3)

SOUTH JETTY STUDY

AVERAGE SALINITY PROFILES ALONG THALWEG OF NORTH CHANNEL



TEST CONDITIONS

TIDE RANGE AT STA 406 (PIT)	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESHWATER DISCHARGE	140,000 CFS

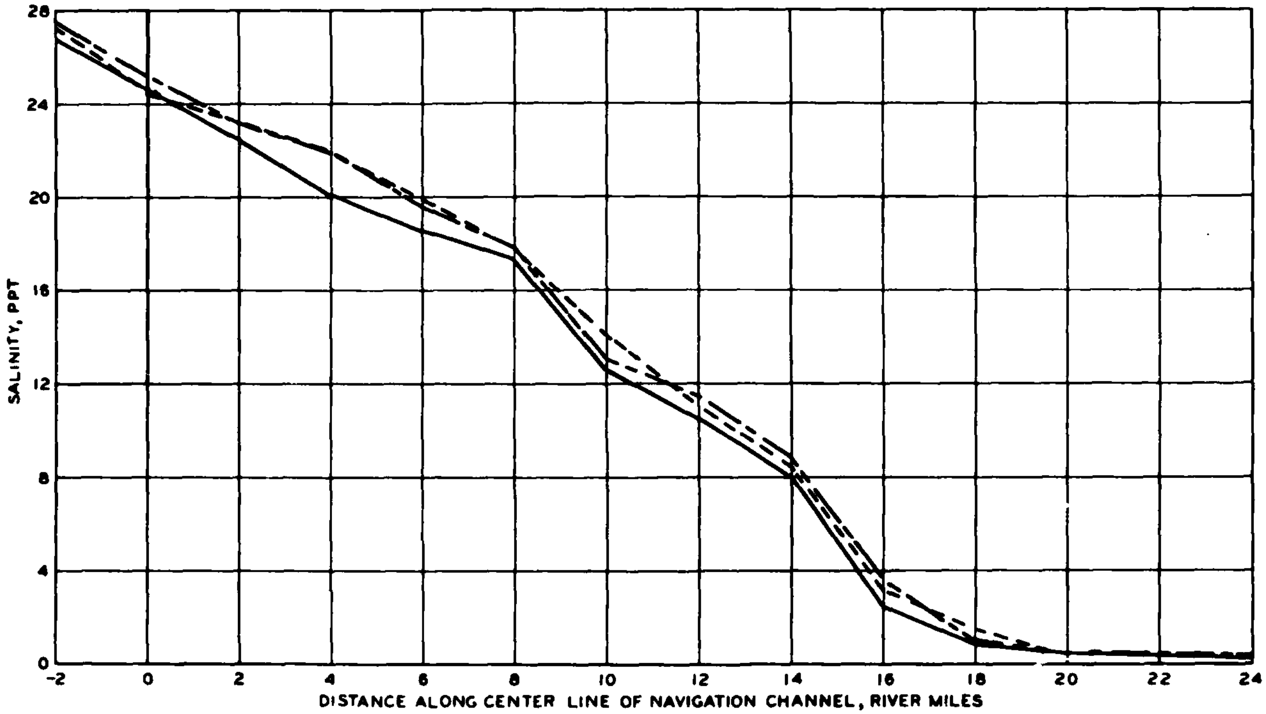
LEGEND

- BASE (A0)
- AUTHORIZED (B1)
- DEGRADED (B2)
- REHAB (B3)

SOUTH JETTY STUDY

MAXIMUM AND MINIMUM SALINITY PROFILE ALONG THALWEG OF NORTH CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM



TEST CONDITIONS

TIDE RANGE AT STATION 406 (PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

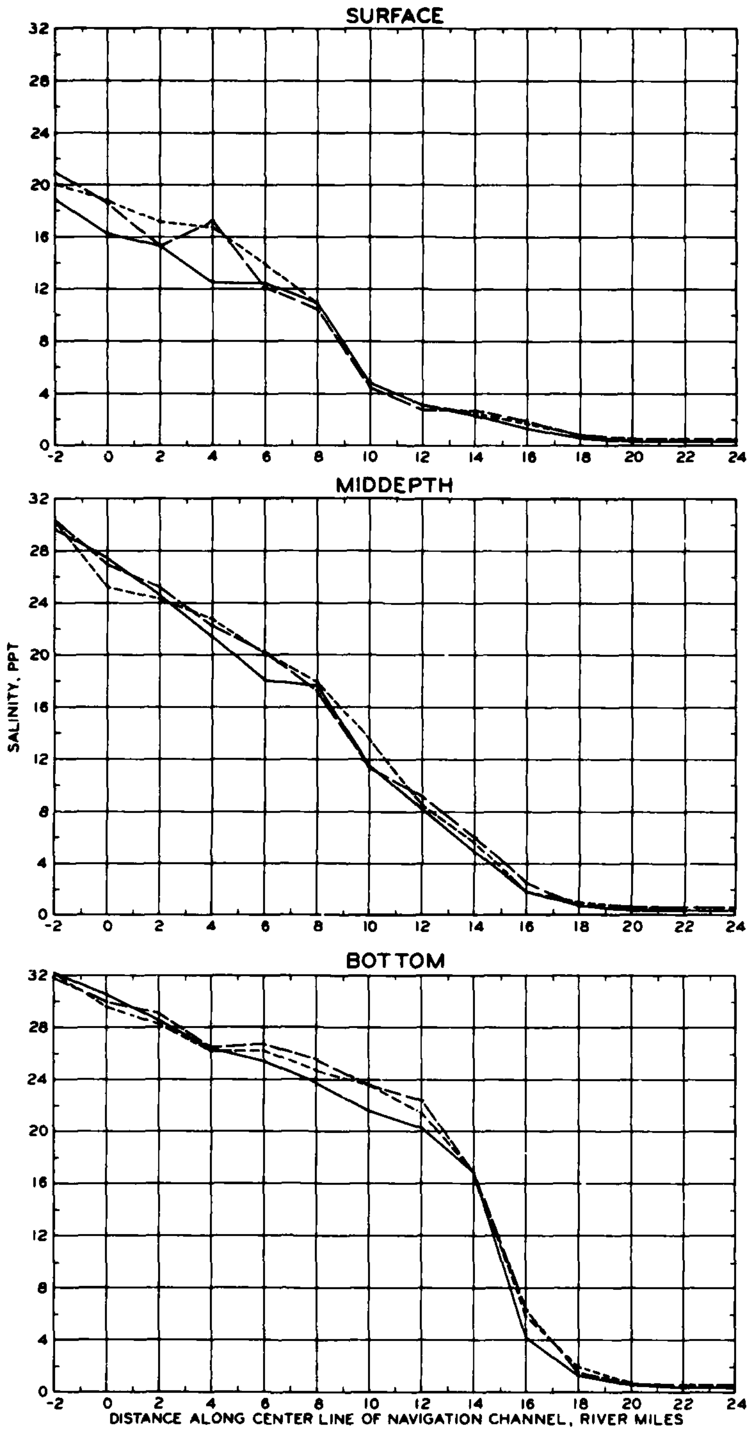
LEGEND

BASE (A0)
PLAN (F0) FULL HEIGHT
PLAN (F1) -10 FT HEIGHT

JETTY B STUDY
(48-FT CHANNEL)

AVERAGE SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: AVERAGE OF SURFACE, MIDDEPTH, AND BOTTOM



TEST CONDITIONS

TIDE RANGE AT STA 406 (PIT)	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESHWATER DISCHARGE	140,000 CFS

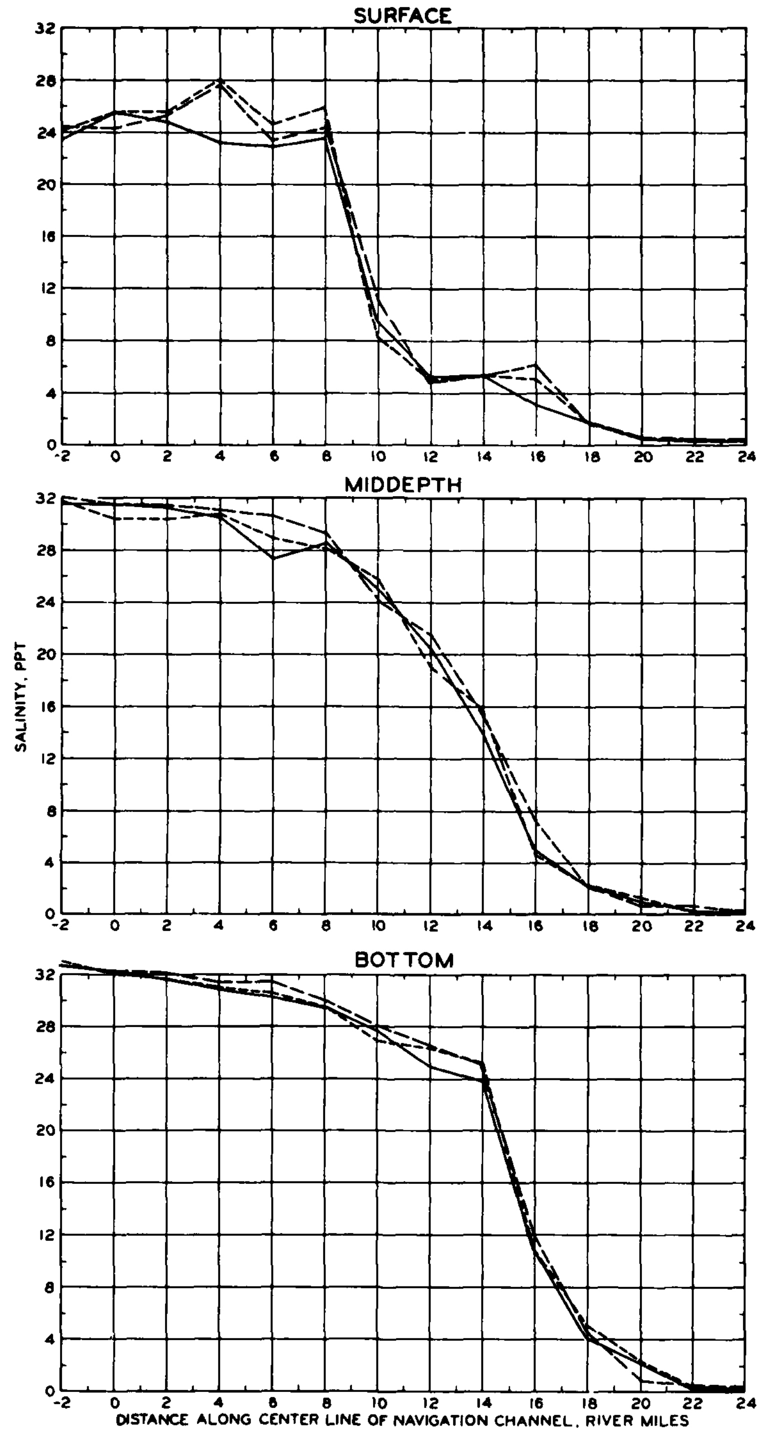
LEGEND

——— BASE (A0)
- - - - PLAN (F0)
— — — PLAN (F1)

JETTY B STUDY
(48-FT CHANNEL)

AVERAGE SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM



TEST CONDITIONS

TIDE RANGE AT STA 406 (PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

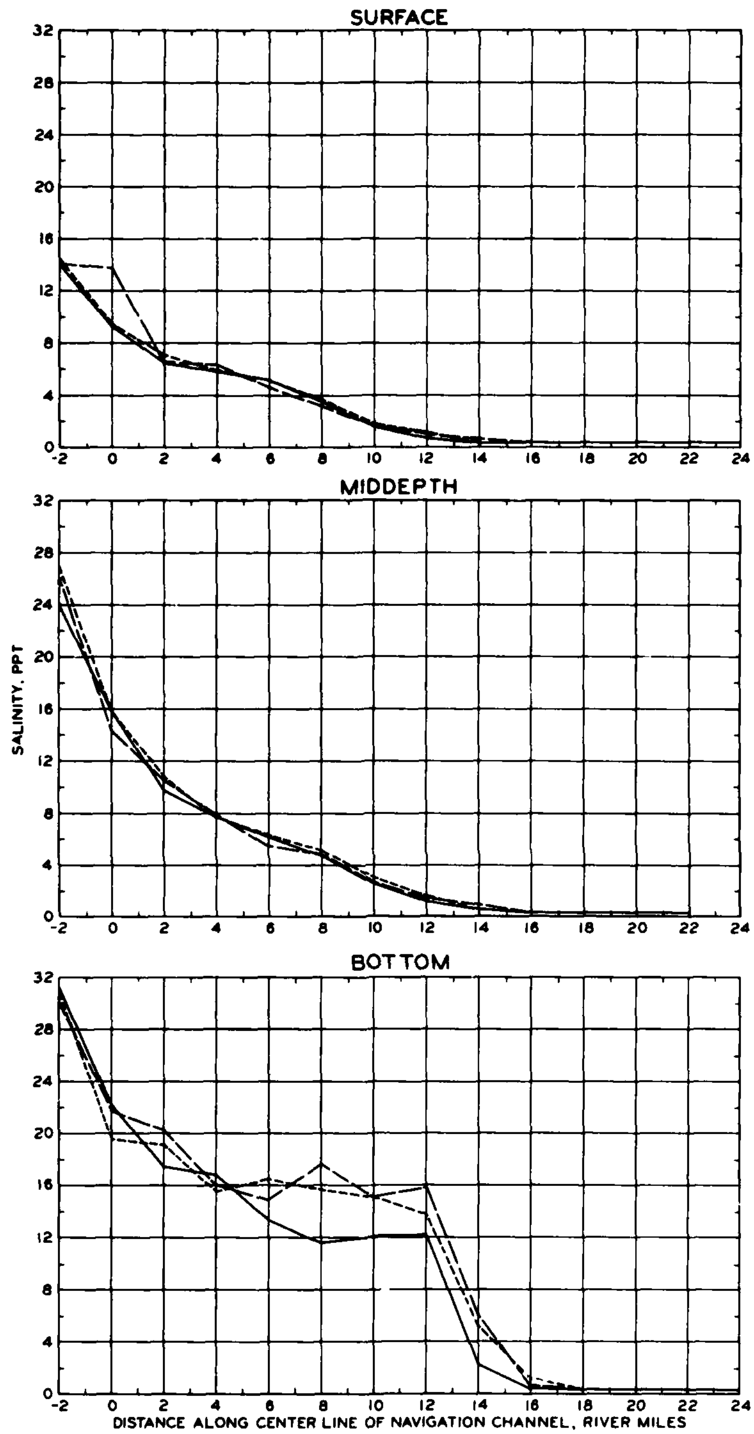
LEGEND

—— BASE (A0)
---- PLAN (F0)
— — PLAN (F1)

JETTY B STUDY
(48-FT CHANNEL)

MAXIMUM SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM



TEST CONDITIONS

TIDE RANGE AT STA 406 (PIT)	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESHWATER DISCHARGE	140,000 CFS

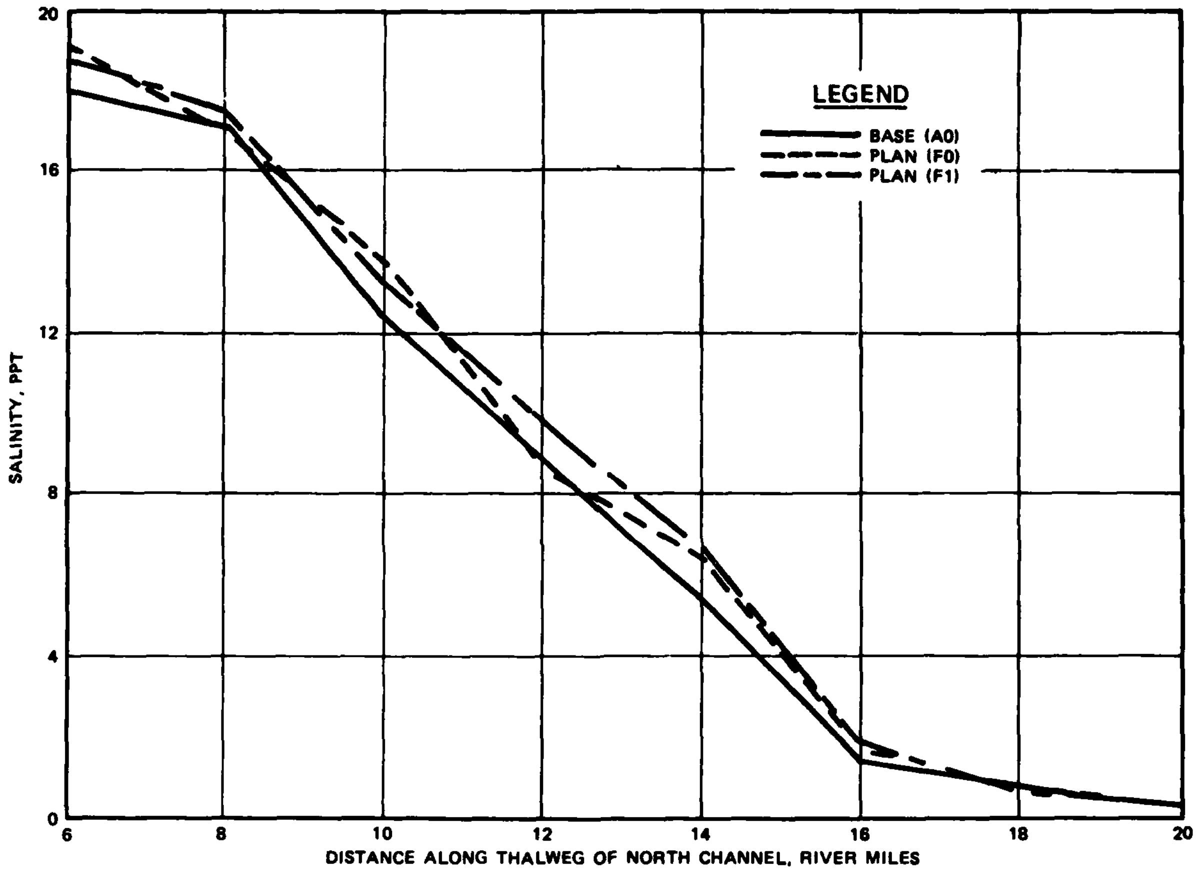
LEGEND

—— BASE (A0)
----- PLAN (F0)
— — PLAN (F1)

JETTY B STUDY
(48-FT CHANNEL)

MINIMUM SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM



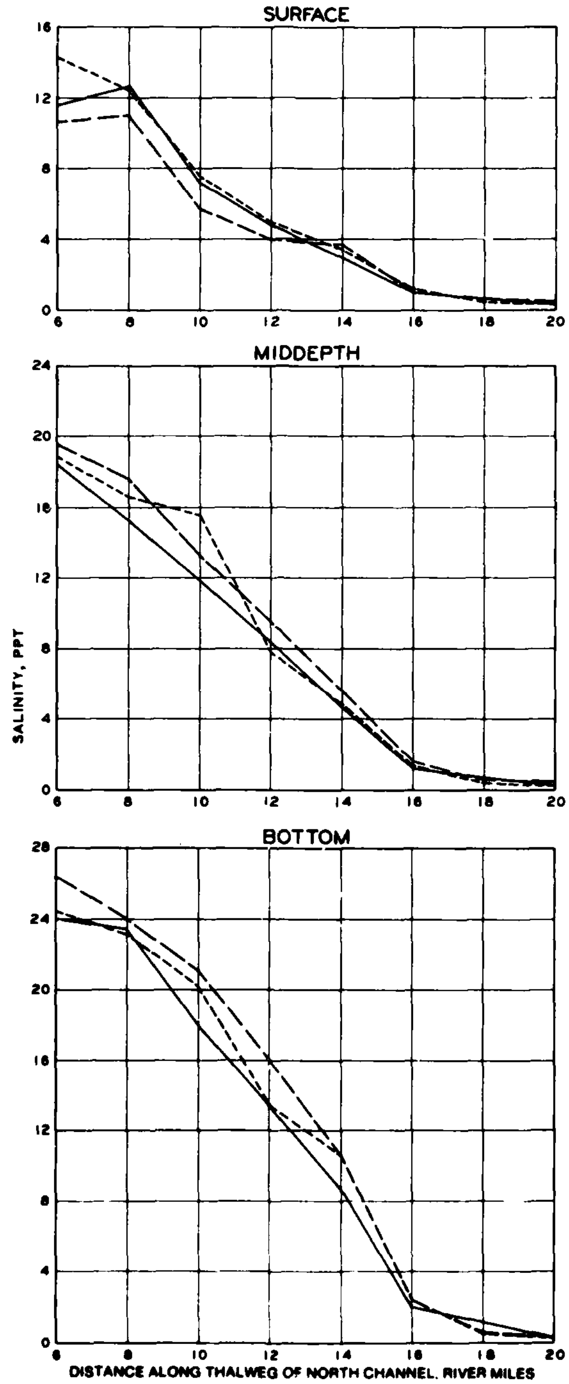
TEST CONDITION

TIDE RANGE AT STATION 406 (PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

JETTY B STUDY
(48-FT CHANNEL)

AVERAGE SALINITY PROFILE ALONG THALWEG OF NORTH CHANNEL

DEPTH: AVERAGE OF SURFACE, MIDDEPTH, AND BOTTOM



TEST CONDITIONS

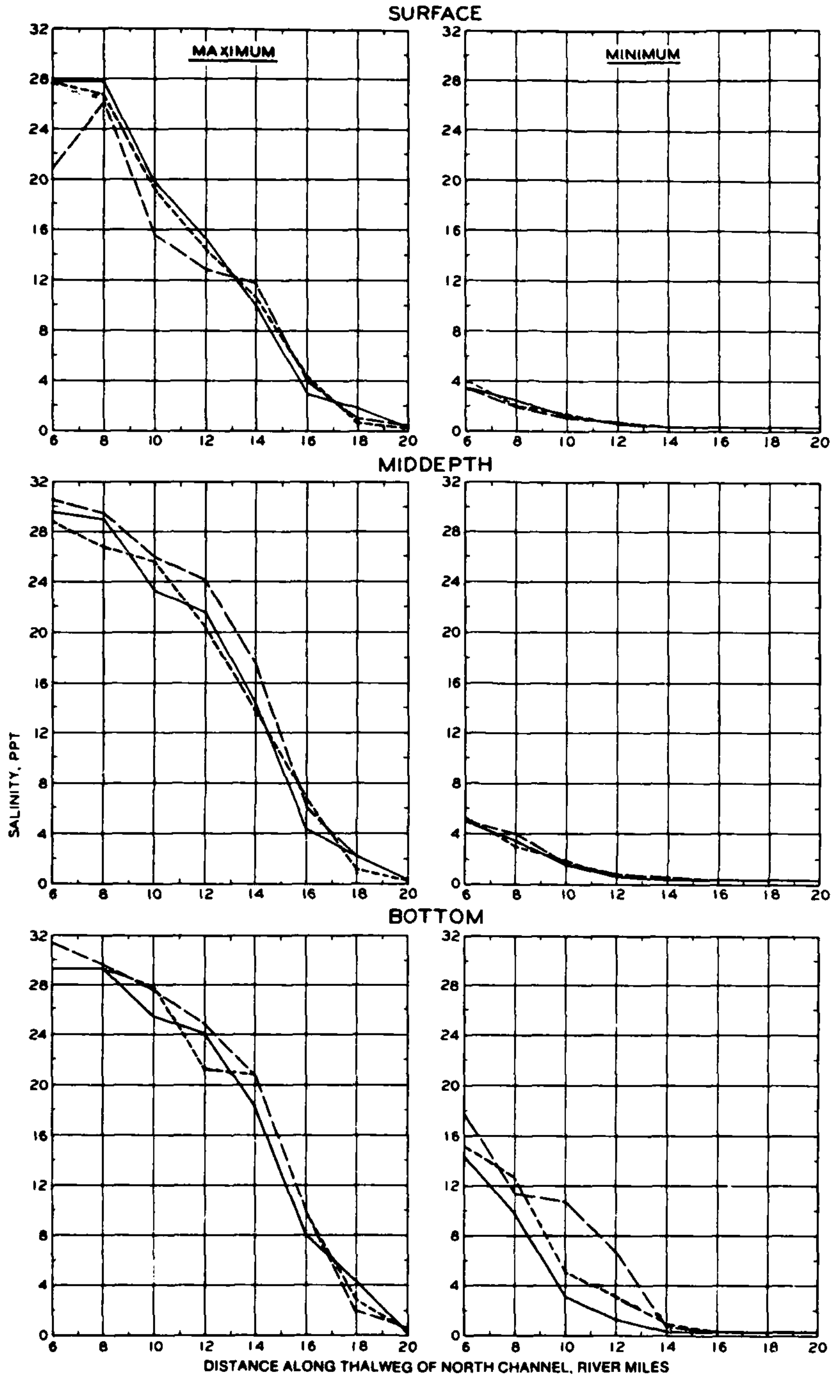
TIDE RANGE AT STATION 406(PIT) 8.85 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

LEGEND

——— BASE (A0)
- - - - PLAN (F0)
— — — PLAN (F1)

JETTY B STUDY
(48-FT CHANNEL)

AVERAGE SALINITY PROFILES ALONG THALWEG OF NORTH CHANNEL



TEST CONDITIONS

TIDE RANGE AT STA 406 (PIT)	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESHWATER DISCHARGE	140,000 CFS

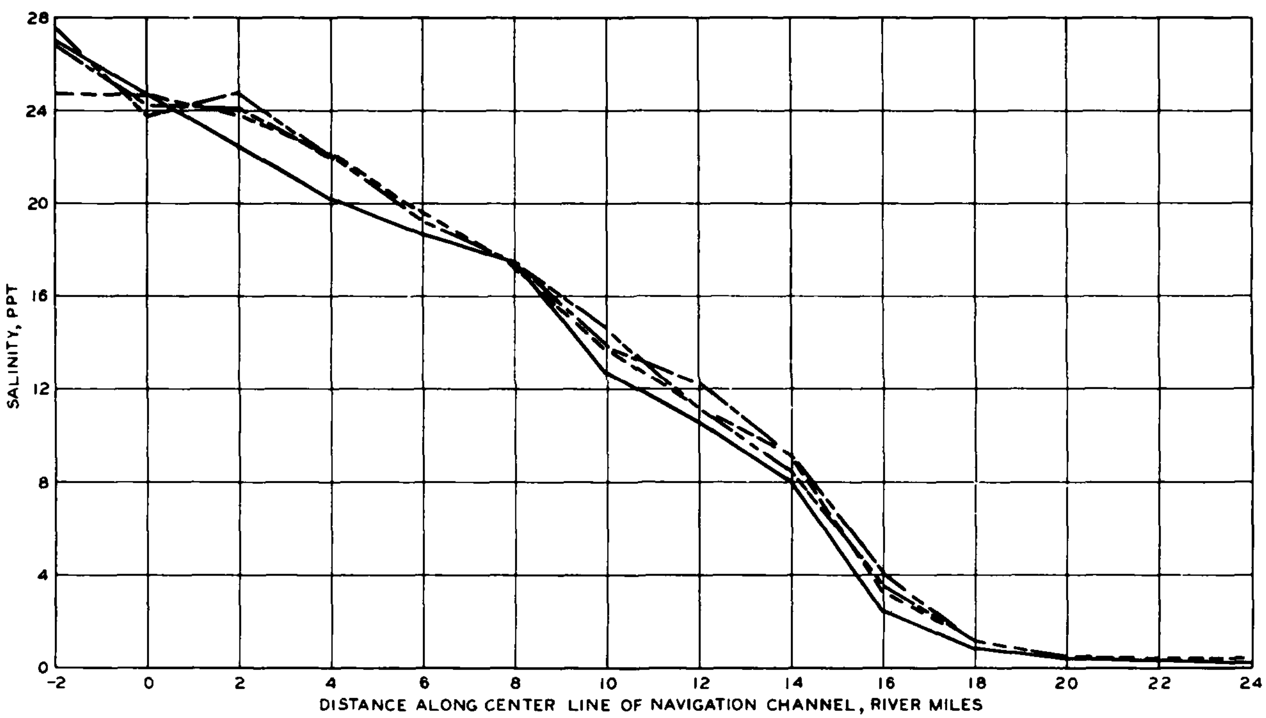
LEGEND

——— BASE (AO)
-·-·- PLAN (FO)
— — PLAN (F1)

JETTY B STUDY
(48-FT CHANNEL)

MAXIMUM AND MINIMUM SALINITY PROFILE ALONG THALWEG OF NORTH CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM



TEST CONDITIONS

TIDE RANGE AT STATION 406 (PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

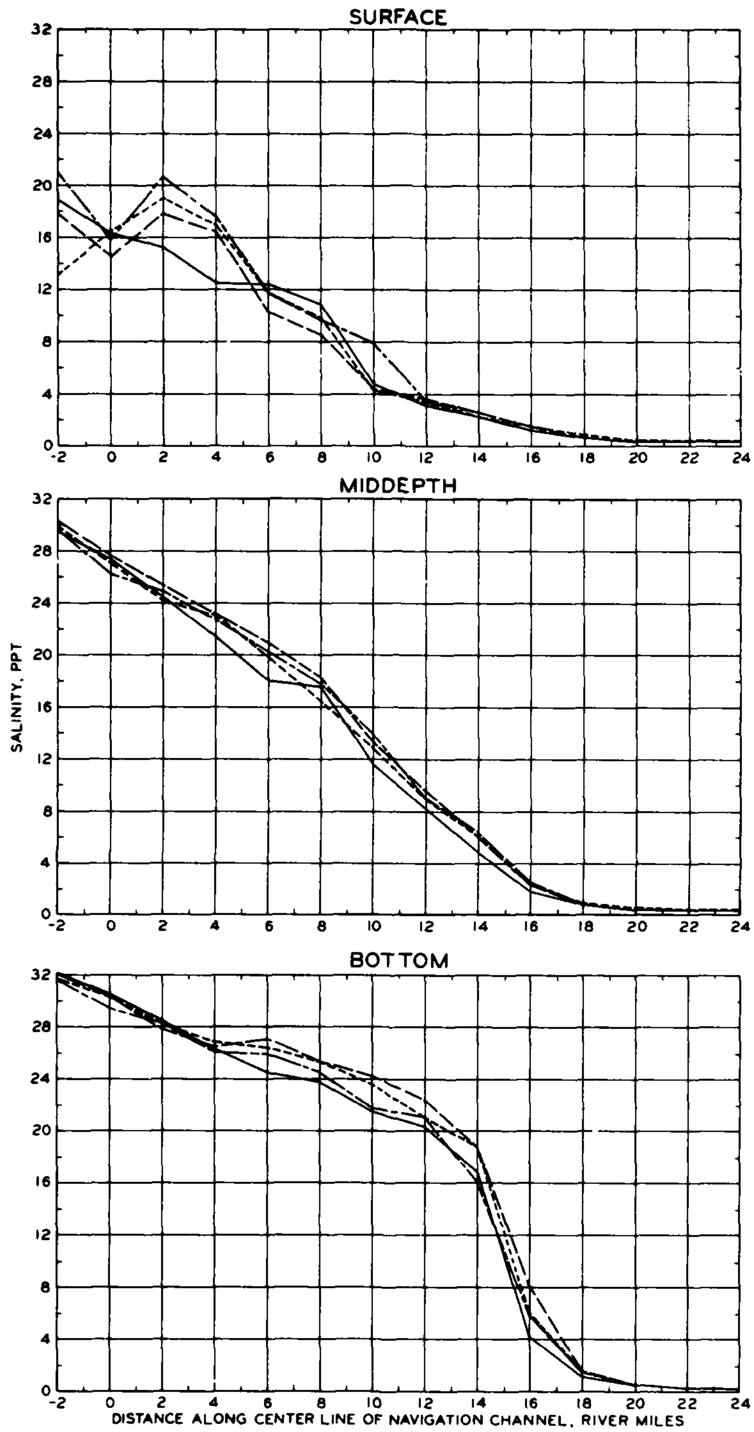
LEGEND

BASE (A0)
PLAN (C0) 55-FT CHANNEL x 2640 FT WIDE
PLAN (C1) FROM 55 FT TO 48 FT
PLAN (C2) 55-FT CHANNEL x 2000 FT WIDE

55-FT (MLLW) CHANNEL STUDY

AVERAGE SALINITY PROFILE ALONG
CENTER LINE OF NAVIGATION CHANNEL

DEPTH: AVERAGE OF SURFACE,
MIDDEPTH, AND BOTTOM



TEST CONDITIONS

TIDE RANGE AT STA 406 (PIT)	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESHWATER DISCHARGE	140,000 CFS

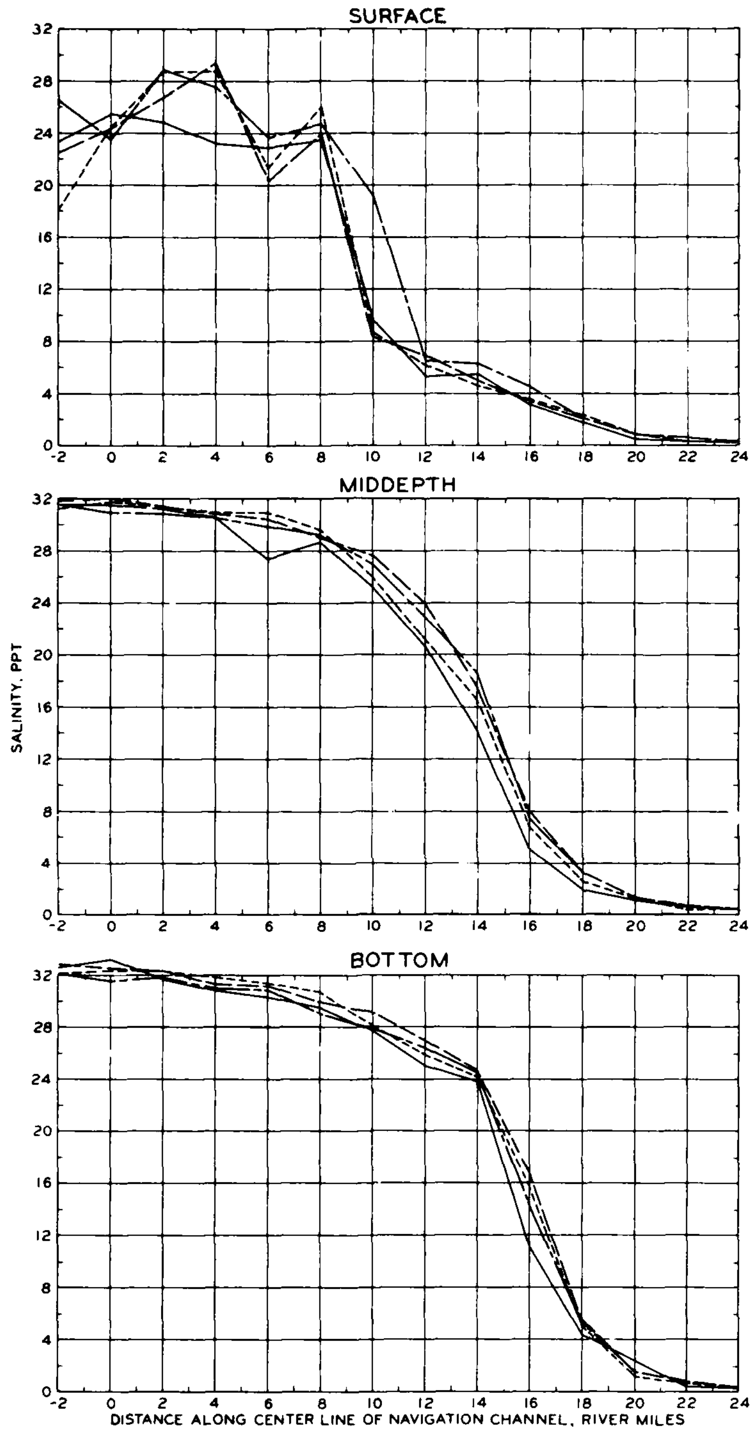
LEGEND

- BASE (A0)
- PLAN (C0)
- PLAN (C1)
- PLAN (C2)

55-FT (MLLW) CHANNEL STUDY

AVERAGE SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM



TEST CONDITIONS

TIDE RANGE AT STA 406 (PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

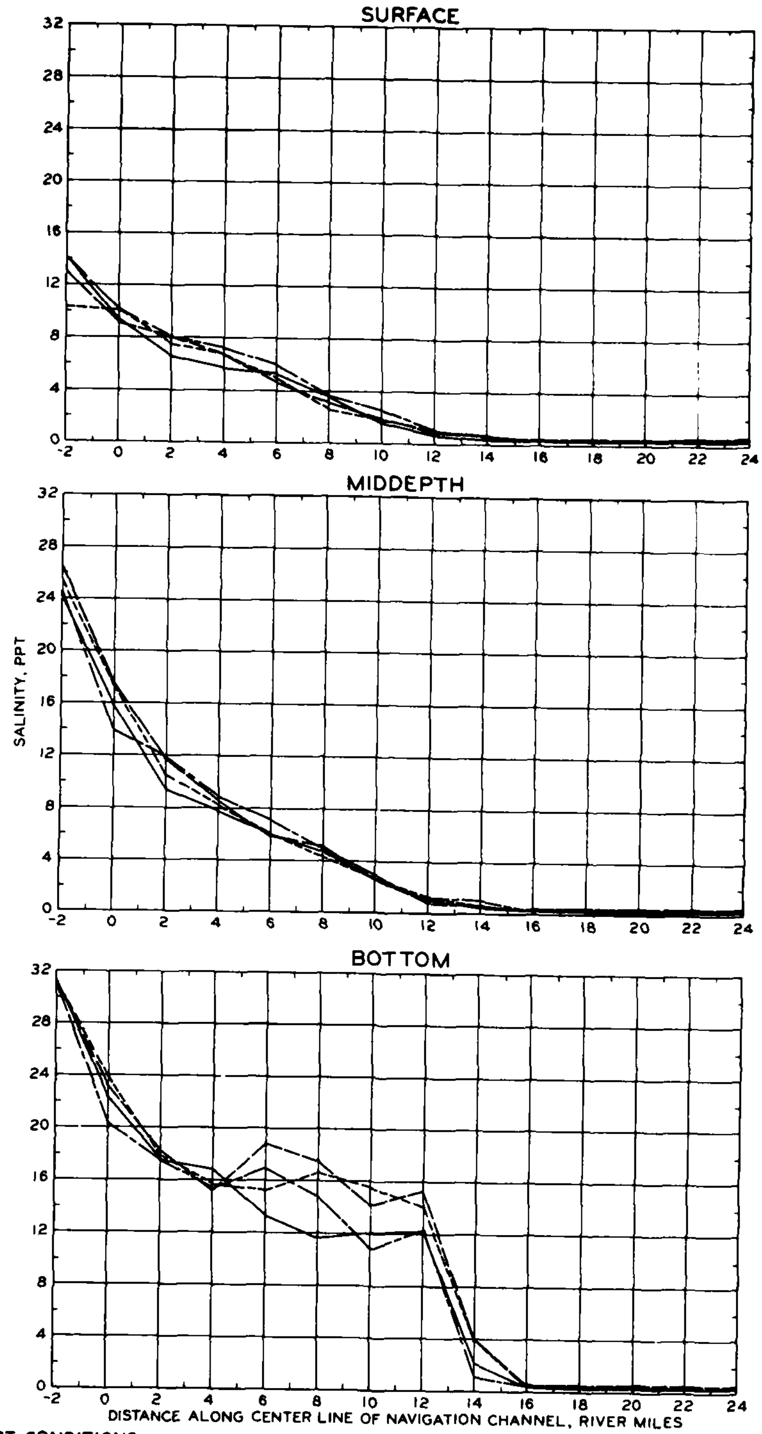
LEGEND

BASE (A0)
PLAN (C0)
PLAN (C1)
PLAN (C2)

55-FT (MLLW) CHANNEL STUDY

MAXIMUM SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM



TEST CONDITIONS

TIDE RANGE AT STA 406 (PIT)	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESHWATER DISCHARGE	140,000 CFS

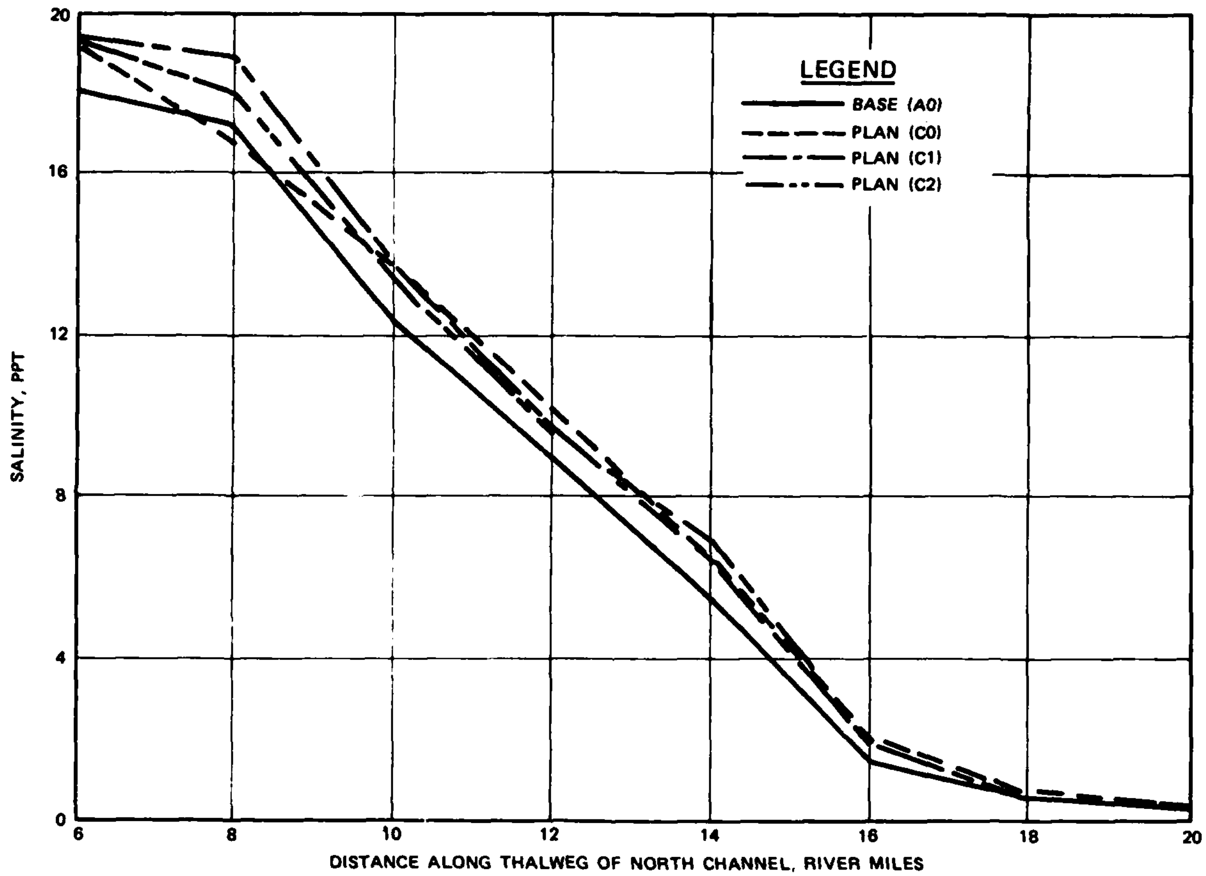
LEGEND

- BASE (A0)
- PLAN (C0)
- PLAN (C1)
- PLAN (C2)

55-FT (MLLW) CHANNEL STUDY

MINIMUM SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM



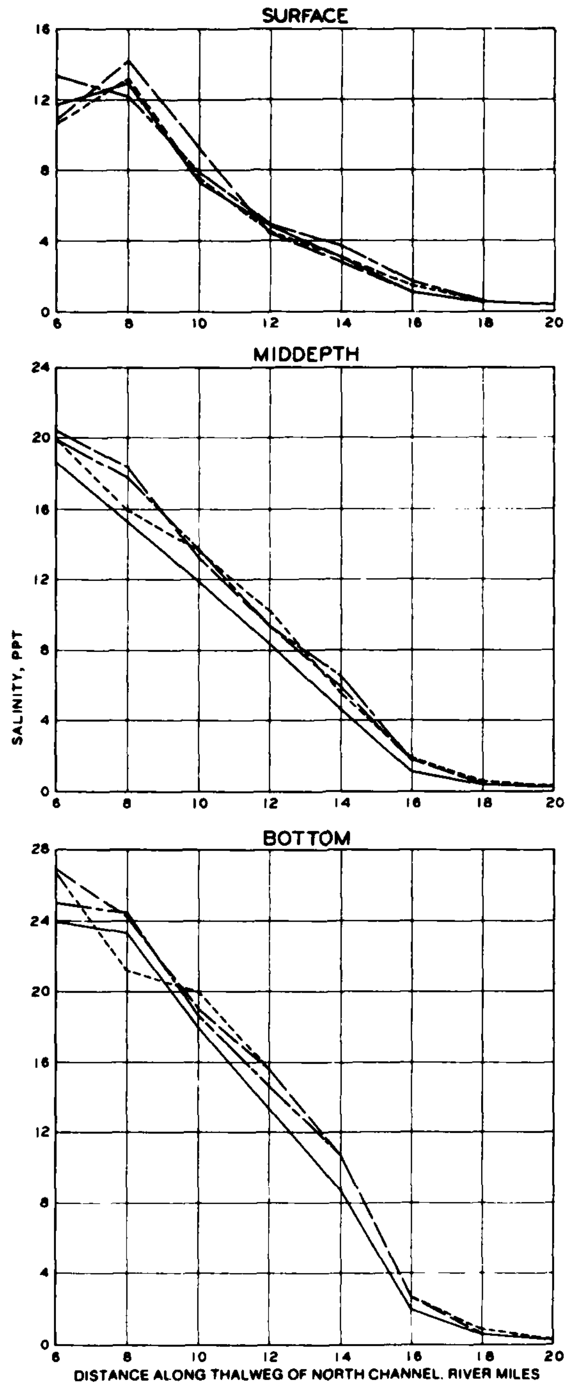
TEST CONDITION

TIDE RANGE AT STATION 406 (PIT)	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESHWATER DISCHARGE	140,000 CFS

55-FT (MLLW) CHANNEL STUDY

AVERAGE SALINITY PROFILE ALONG THALWEG OF NORTH CHANNEL

DEPTH: AVERAGE OF SURFACE, MIDDEPTH, AND BOTTOM



TEST CONDITIONS

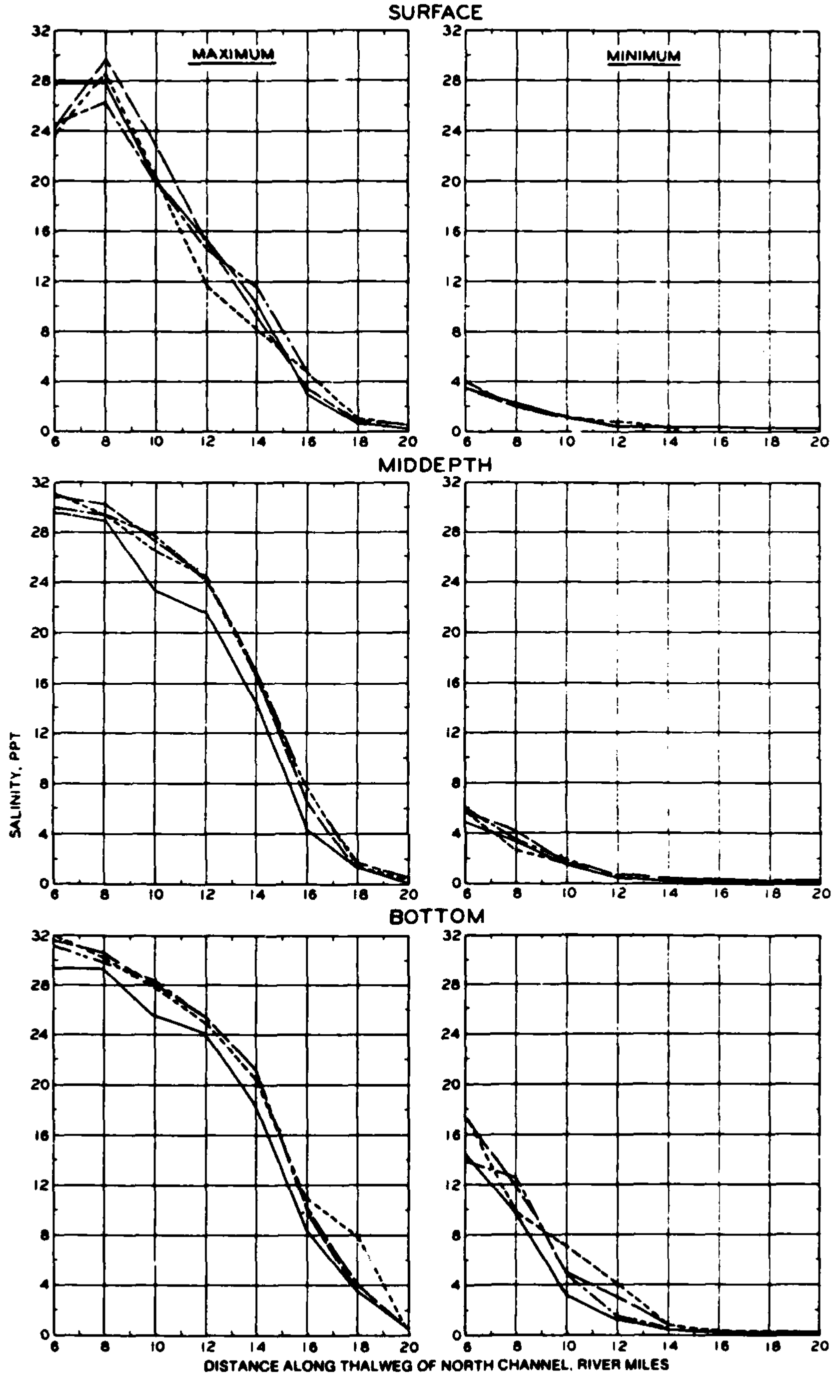
TIDE RANGE AT STATION 406 (PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

LEGEND

BASE (A0)
PLAN (C0)
PLAN (C1)
PLAN (C2)

55-FT (MLLW)
CHANNEL STUDY

AVERAGE SALINITY PROFILES ALONG THALWEG OF NORTH CHANNEL



TEST CONDITIONS

TIDE RANGE AT STA 406 (PIT)	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESHWATER DISCHARGE	140,000 CFS

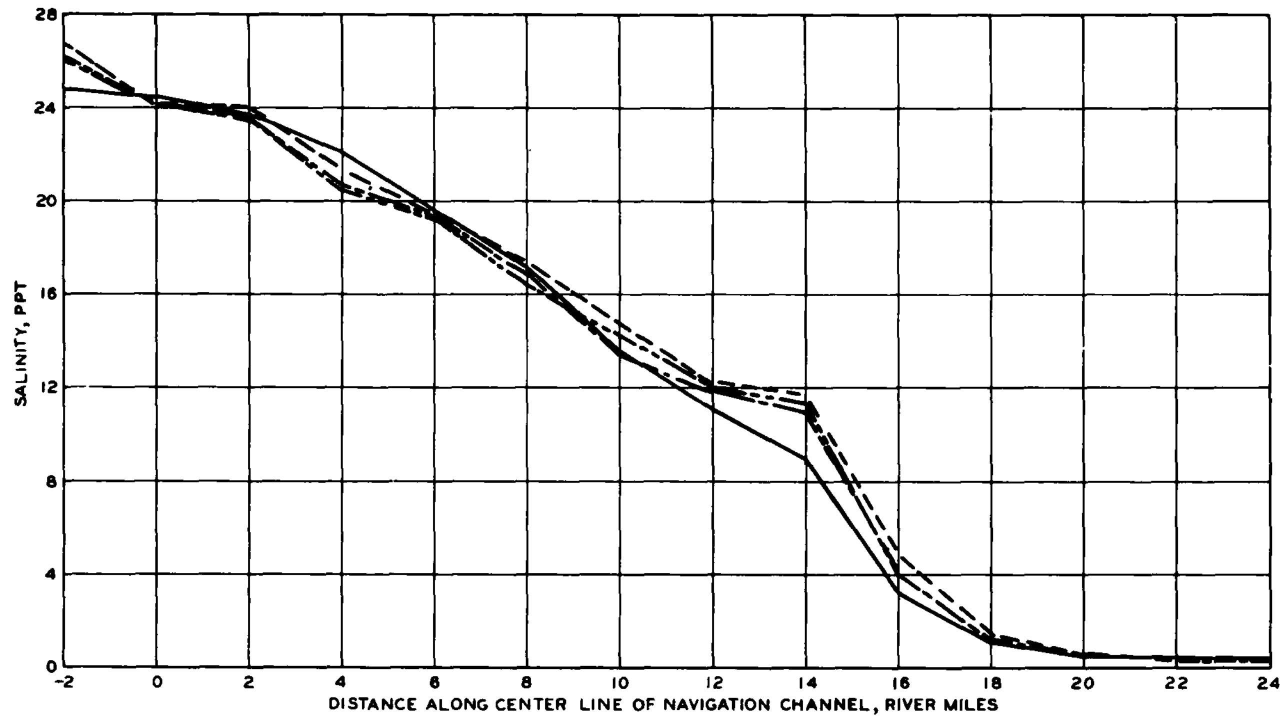
LEGEND

- BASE (A0)
- PLAN (C0)
- PLAN (C1)
- PLAN (C2)

55-FT (MLLW) CHANNEL STUDY

MAXIMUM AND MINIMUM SALINITY PROFILE ALONG THALWEG OF NORTH CHANNEL

DEPTH: SURFACE, MIDDEPTH, BOTTOM



TEST CONDITIONS

TIDE RANGE AT STATION 406 (PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

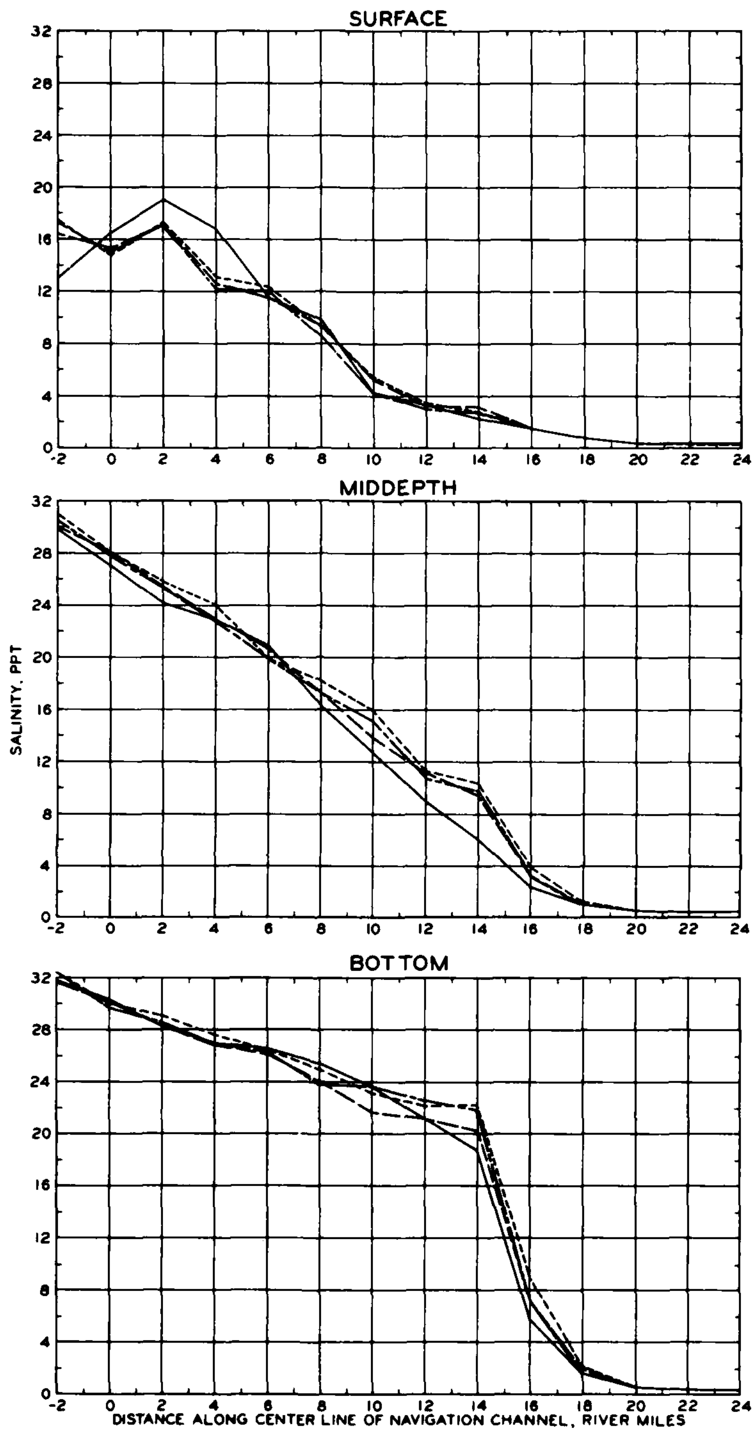
LEGEND

BASE (C0)
PLAN (G0)
PLAN (G1)
PLAN (G2)

JETTY B STUDY
(55-FT CHANNEL)

AVERAGE SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: AVERAGE OF SURFACE, MIDDEPTH, AND BOTTOM



TEST CONDITIONS

TIDE RANGE AT STA 406 (PIT)	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESHWATER DISCHARGE	140,000 CFS

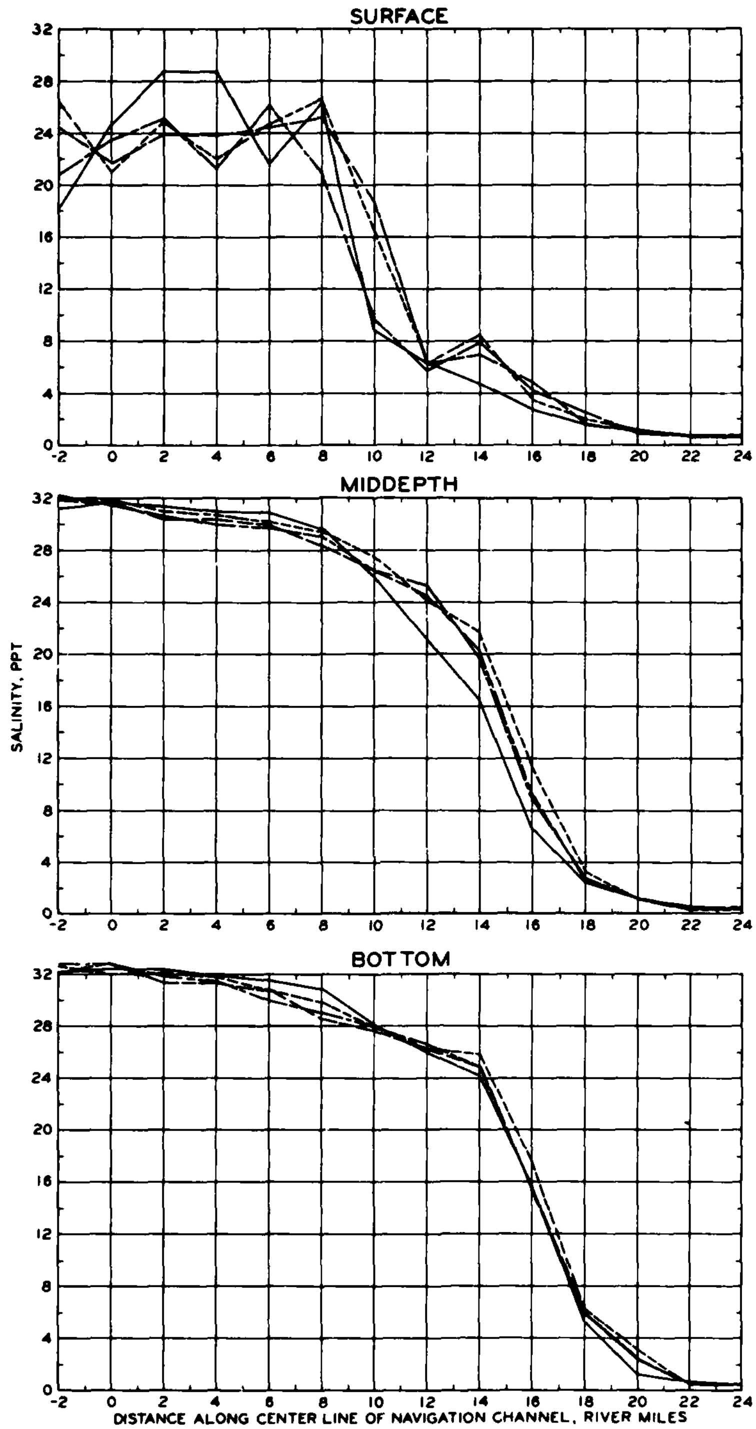
LEGEND

BASE (PLAN C0)
PLAN (G0)
PLAN (G1)
PLAN (G2)

JETTY B STUDY
(55-FT CHANNEL)

AVERAGE SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM



TEST CONDITIONS

TIDE RANGE AT STA 406 (PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

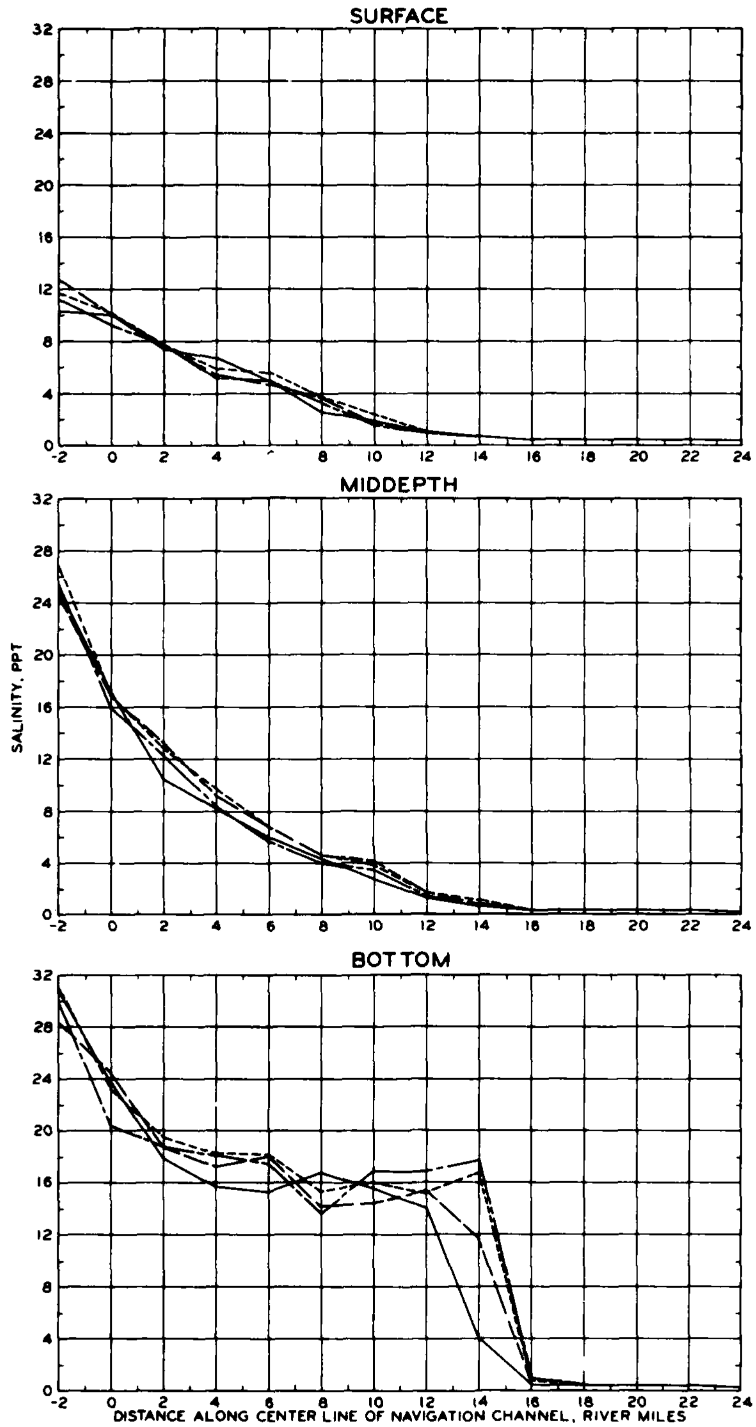
LEGEND

BASE (G0)
PLAN (G0)
PLAN (G1)
PLAN (G2)

JETTY B STUDY
(55-FT CHANNEL)

MAXIMUM SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM



TEST CONDITIONS

TIDE RANGE AT STA 406 (PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

LEGEND

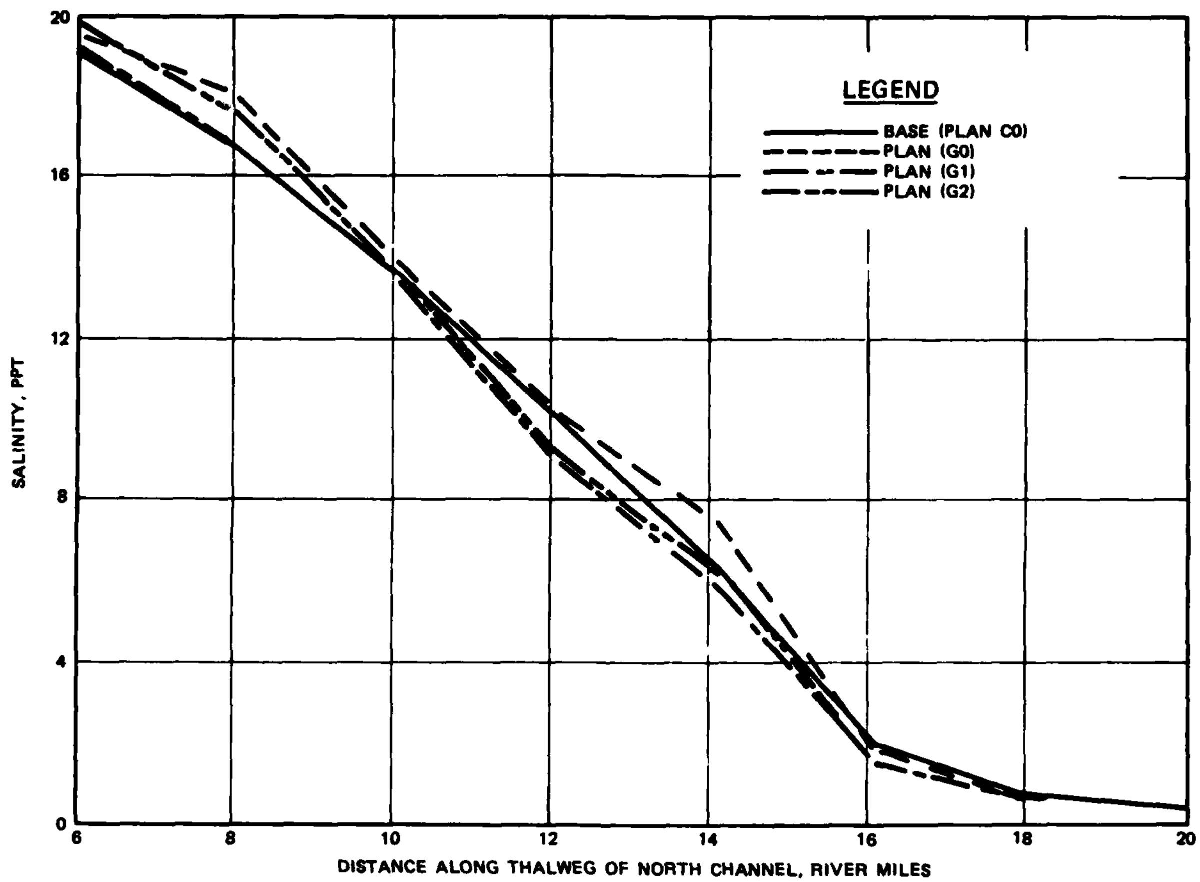
——— BASE (PLAN C0)
- - - - PLAN (G0)
— — — PLAN (G1)
—·—·— PLAN (G2)

COLUMBIA RIVER MODEL

JETTY B STUDY
(55-FT CHANNEL)

MINIMUM SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM



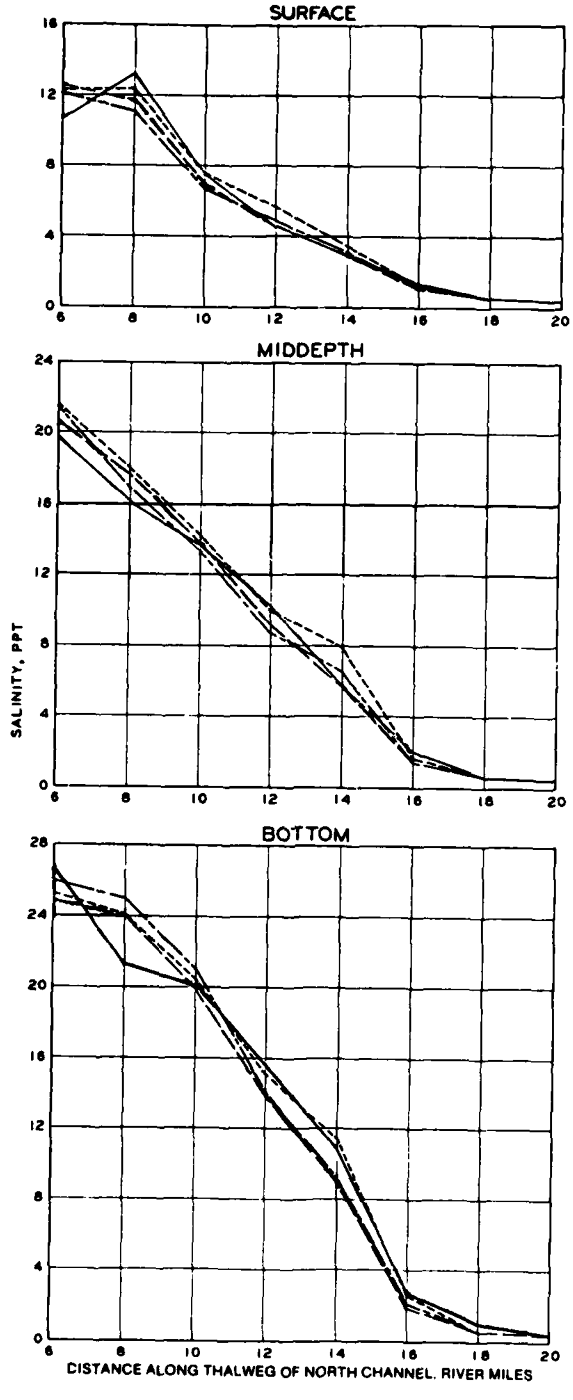
TEST CONDITION

TIDE RANGE AT STATION 406 (PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

JETTY B STUDY
(55-FT CHANNEL)

AVERAGE SALINITY PROFILE ALONG THALWEG OF NORTH CHANNEL

DEPTH: AVERAGE OF SURFACE, MIDDEPTH, AND BOTTOM



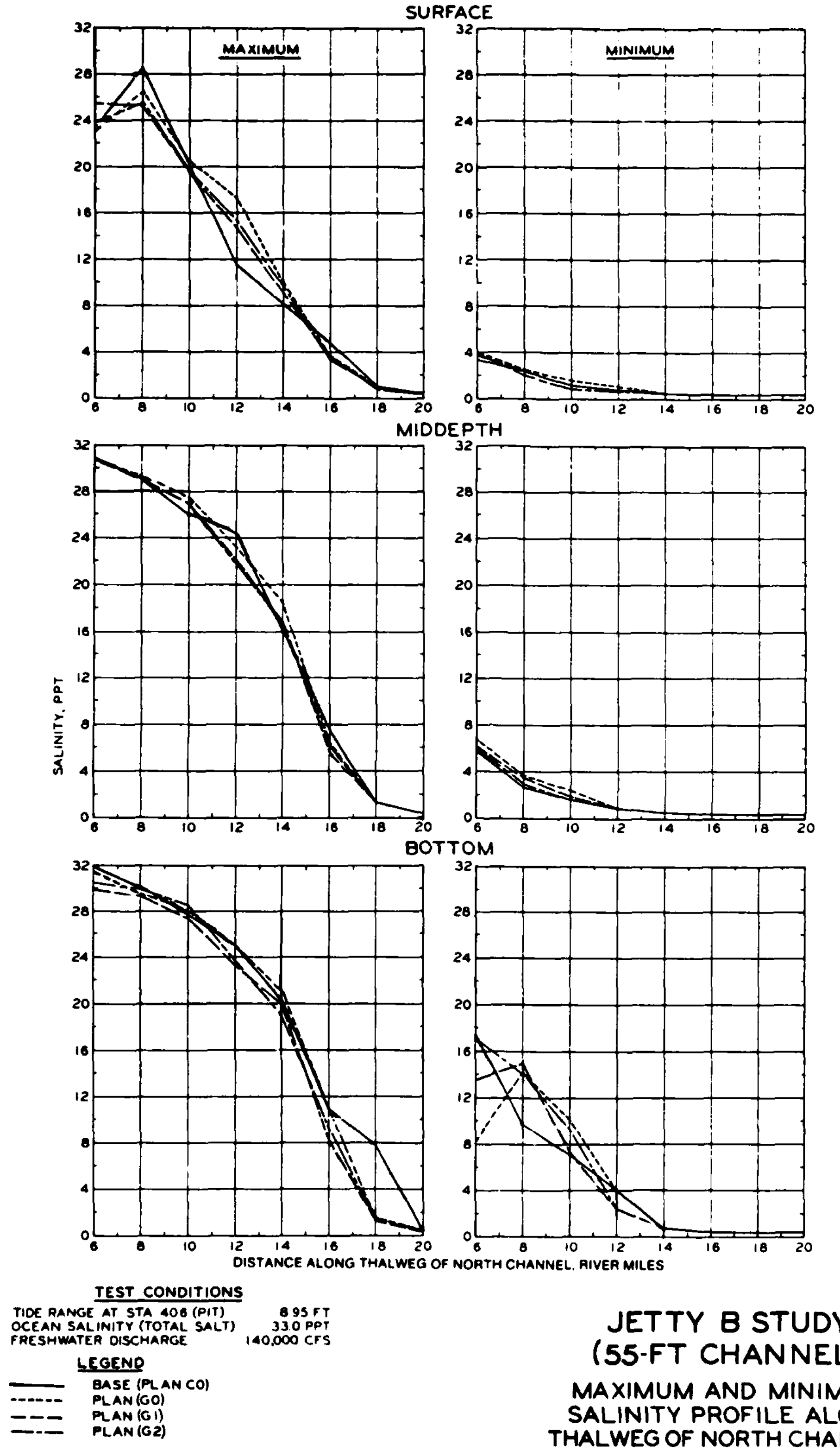
TEST CONDITIONS

TIDE RANGE AT STATION 406 (PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

LEGEND

- BASE (PLAN C0)
- PLAN (G0)
- PLAN (G1)
- PLAN (G2)

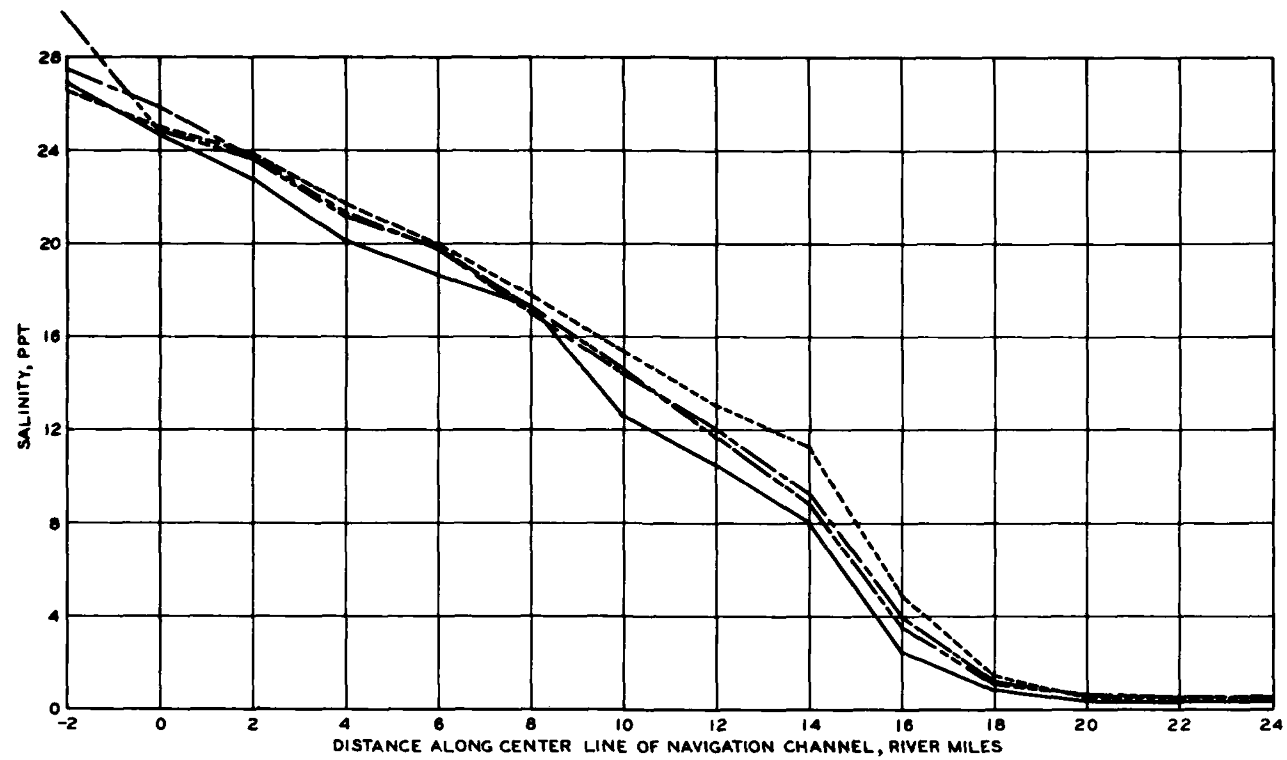
JETTY B STUDY
(55-FT CHANNEL)
AVERAGE SALINITY PROFILES ALONG
THALWEG OF NORTH CHANNEL



JETTY B STUDY
(55-FT CHANNEL)

MAXIMUM AND MINIMUM SALINITY PROFILE ALONG THALWEG OF NORTH CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM



TEST CONDITIONS

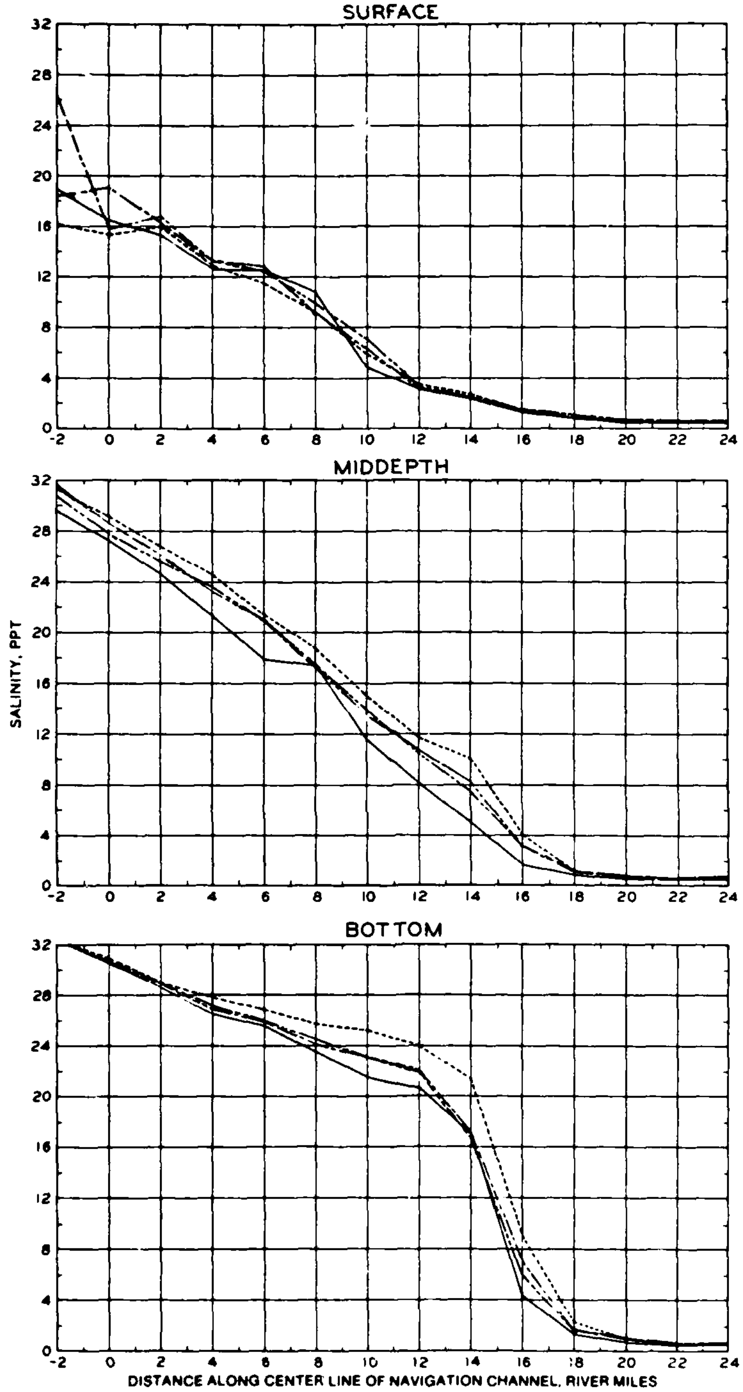
TIDE RANGE AT STATION 406 (PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140.000 CFS

LEGEND

———— BASE A0
- - - - - PLAN H0
—— - —— PLAN H1
—— - - —— PLAN I0

EFFECTS OF PLANS H0, H1, AND I0 ON AVERAGE SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: AVERAGE OF SURFACE, MIDDEPTH, AND BOTTOM



TEST CONDITIONS

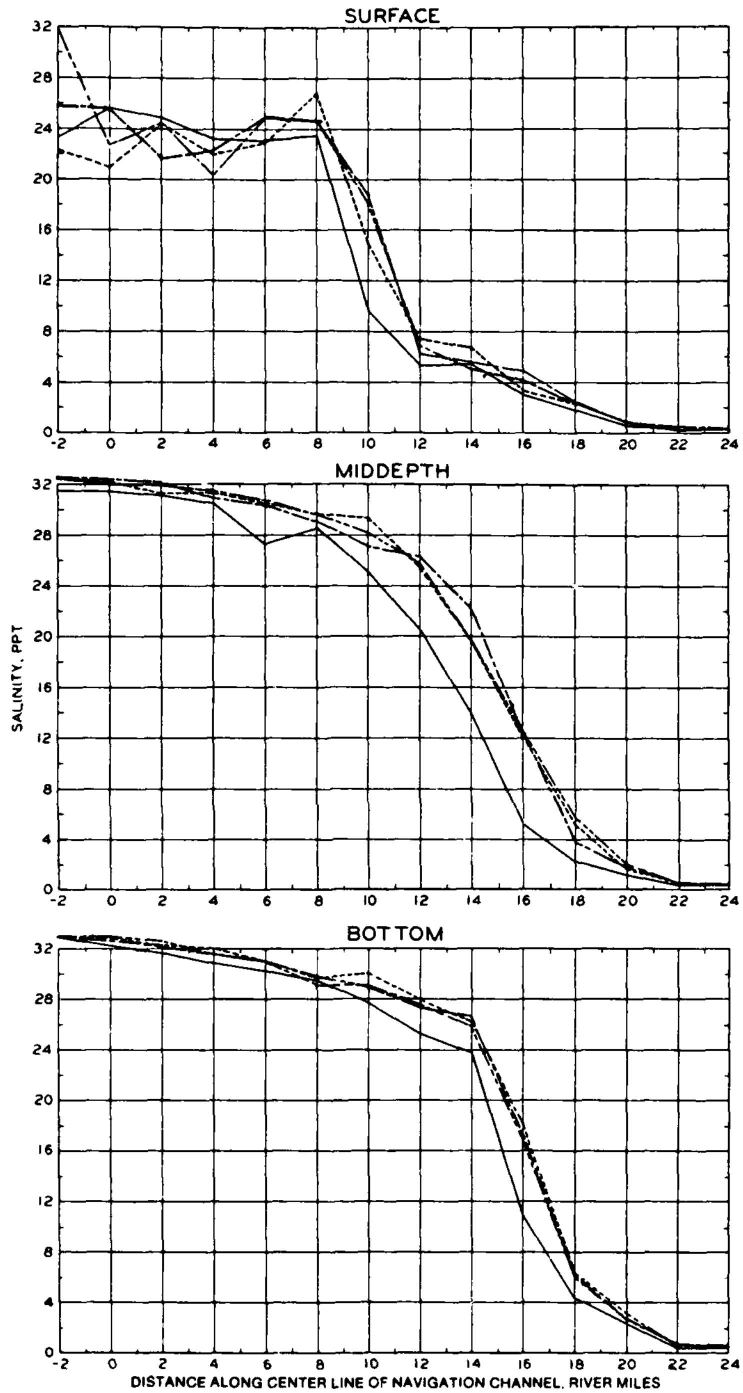
TIDE RANGE AT STA 406 (PIT)	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESHWATER DISCHARGE	140,000 CFS

LEGEND

- BASE A0
- PLAN H0
- PLAN H1
- PLAN I0

EFFECTS OF PLANS H0, H1, AND I0 ON AVERAGE SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM



TEST CONDITIONS

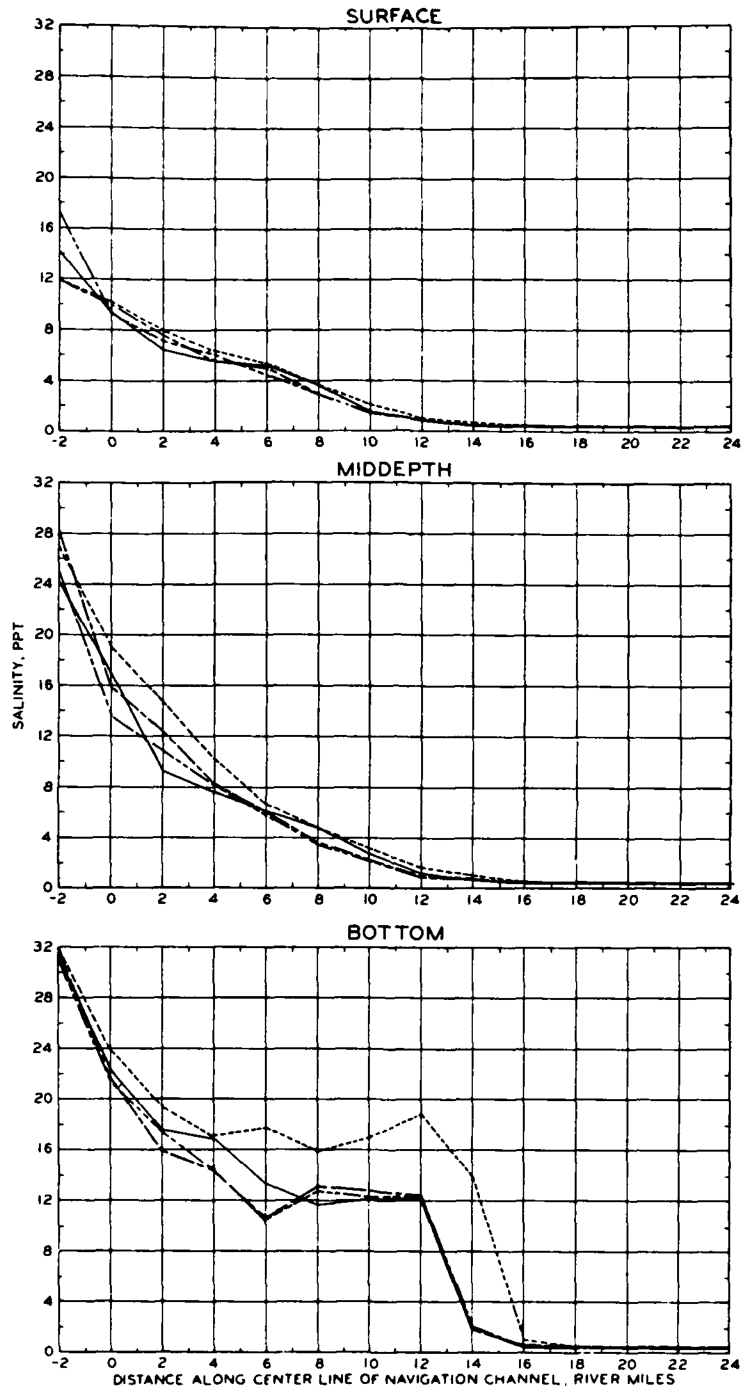
TIDE RANGE AT STA 406 (PIT)	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESHWATER DISCHARGE	140,000 CFS

LEGEND

- BASE A0
- PLAN H0
- PLAN H1
- PLAN I0

EFFECTS OF PLANS H0 , H1, AND I0 ON MAXIMUM SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM



TEST CONDITIONS

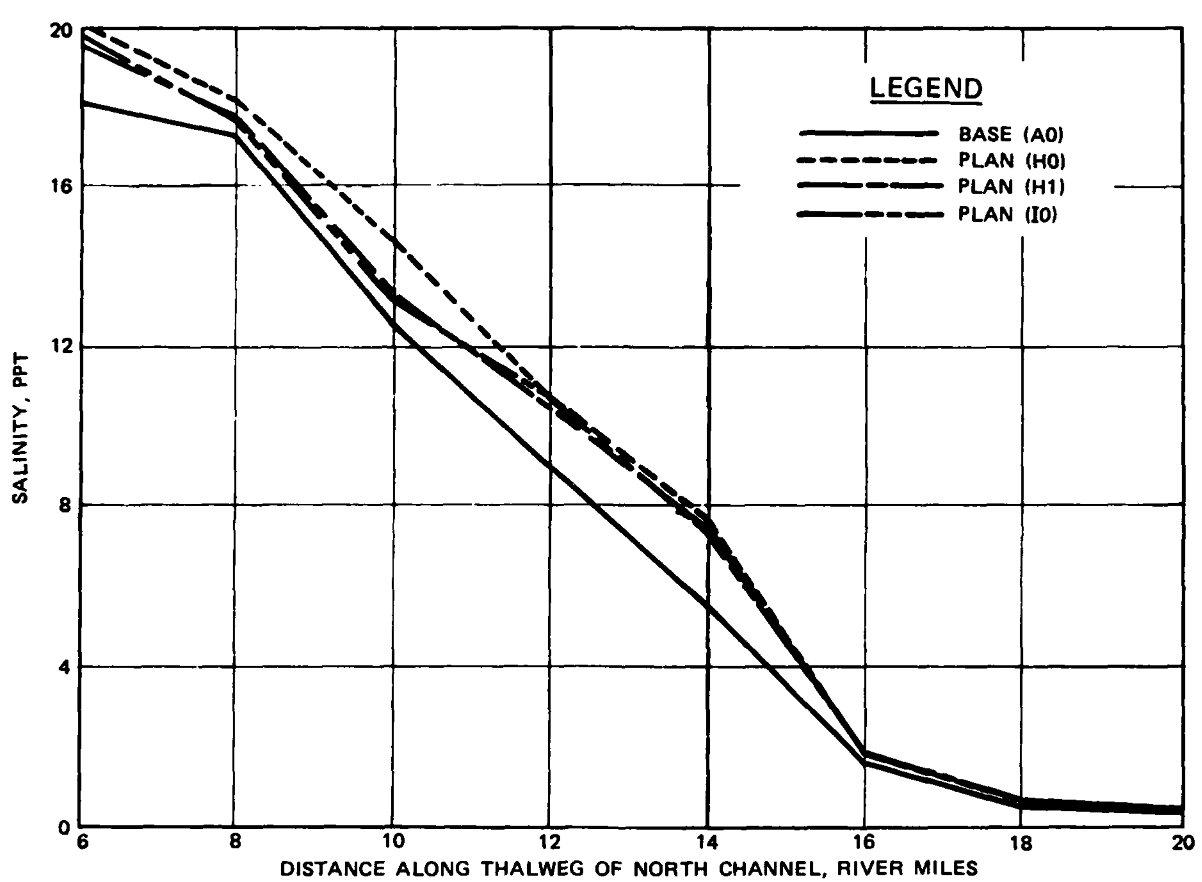
TIDE RANGE AT STA 406 (PIT)	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESHWATER DISCHARGE	140,000 CFS

LEGEND

- BASE A0
- PLAN H0
- PLAN H1
- PLAN I0

EFFECTS OF PLANS H0, H1, AND I0 ON MINIMUM SALINITY PROFILE ALONG CENTER LINE OF NAVIGATION CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM

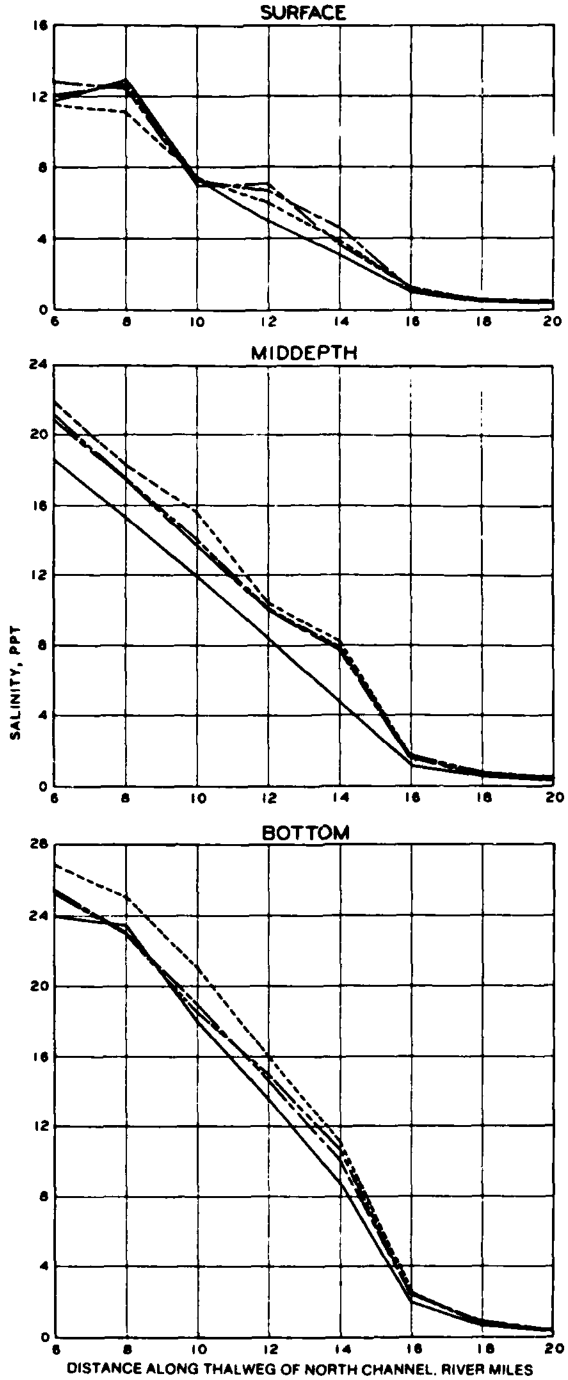


TEST CONDITION

TIDE RANGE AT STATION 406 (PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

EFFECTS OF PLANS H0, H1, AND I0 ON AVERAGE SALINITY PROFILE ALONG THALWEG OF NORTH CHANNEL

DEPTH: AVERAGE OF SURFACE, MIDDEPTH, AND BOTTOM



TEST CONDITIONS

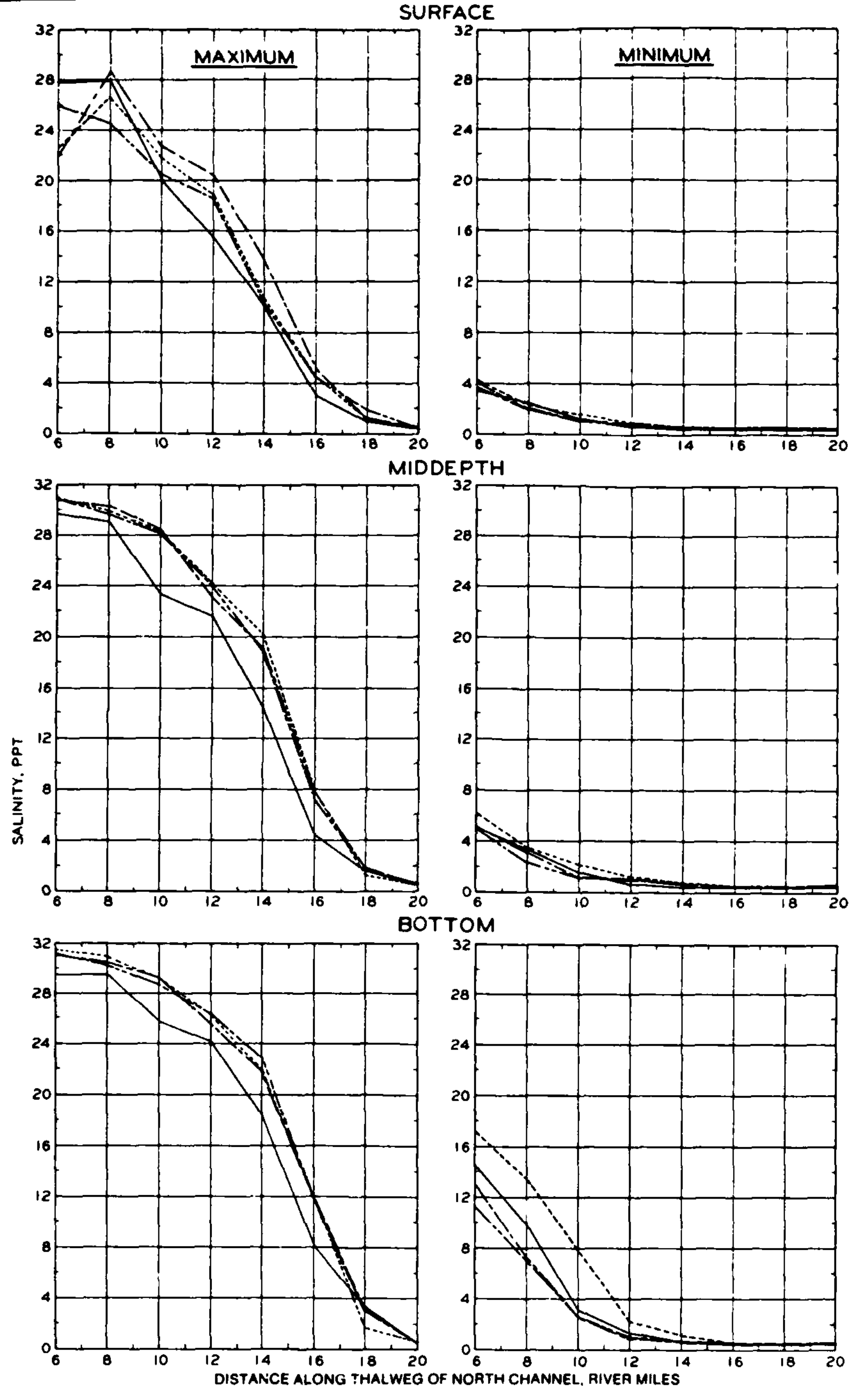
TIDE RANGE AT STATION 406(PIT) 8.95 FT
OCEAN SALINITY (TOTAL SALT) 33.0 PPT
FRESHWATER DISCHARGE 140,000 CFS

LEGEND

BASE A0
PLAN H0
PLAN H1
PLAN I0

EFFECTS OF PLANS H0, H1, AND I0 ON AVERAGE SALINITY PROFILES ALONG THALWEG OF NORTH CHANNEL

DEPTH: SURFACE; MIDDEPTH; BOTTOM



TEST CONDITIONS

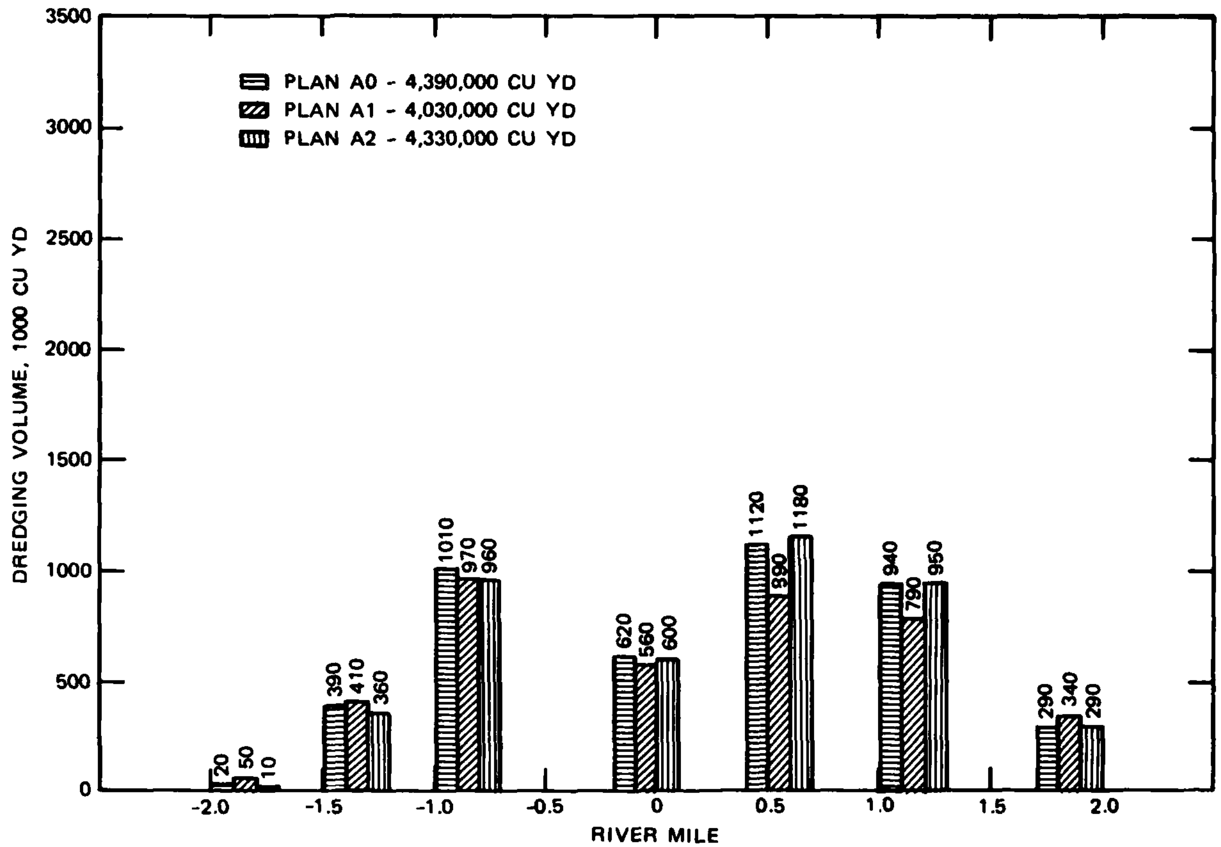
TIDE RANGE AT STA 406 (PIT)	8.95 FT
OCEAN SALINITY (TOTAL SALT)	33.0 PPT
FRESHWATER DISCHARGE	140,000 CFS

LEGEND

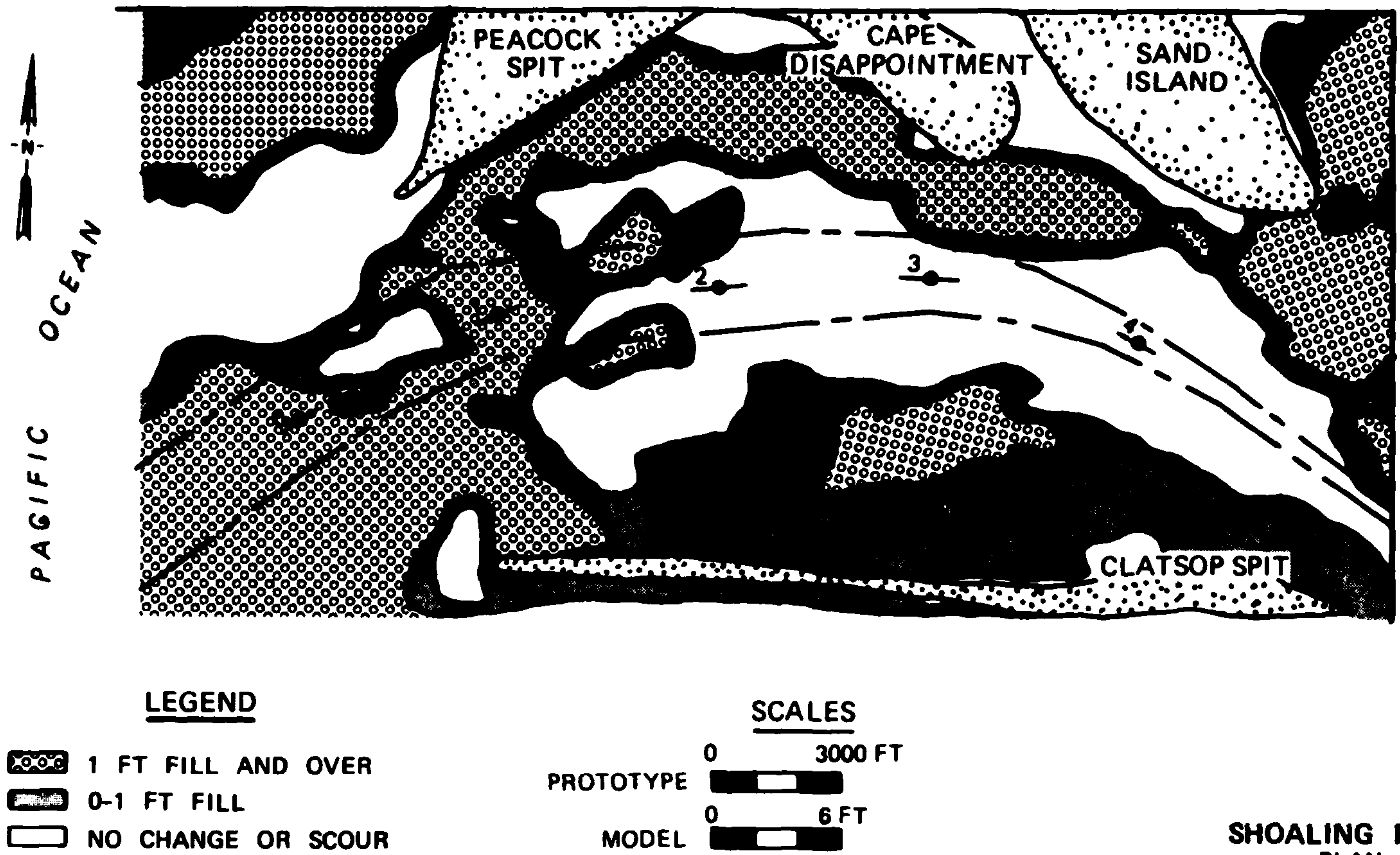
- BASE A0
- PLAN H0
- PLAN H1
- PLAN I0

EFFECTS OF PLANS H0, H1, AND I0 ON MAXIMUM AND MINIMUM SALINITY PROFILE ALONG THALWEG OF NORTH CHANNEL

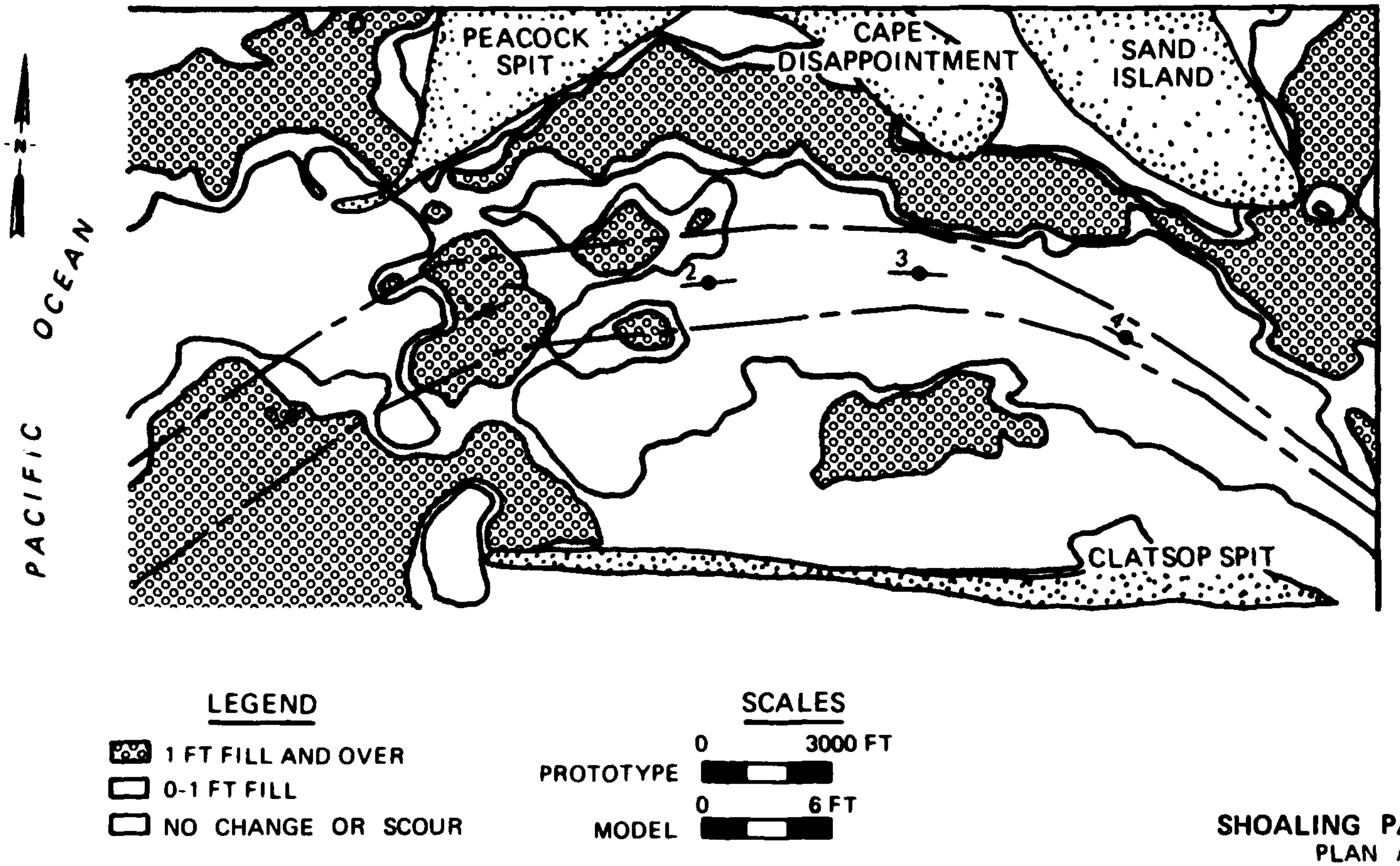
DEPTH: SURFACE; MIDDEPTH; BOTTOM



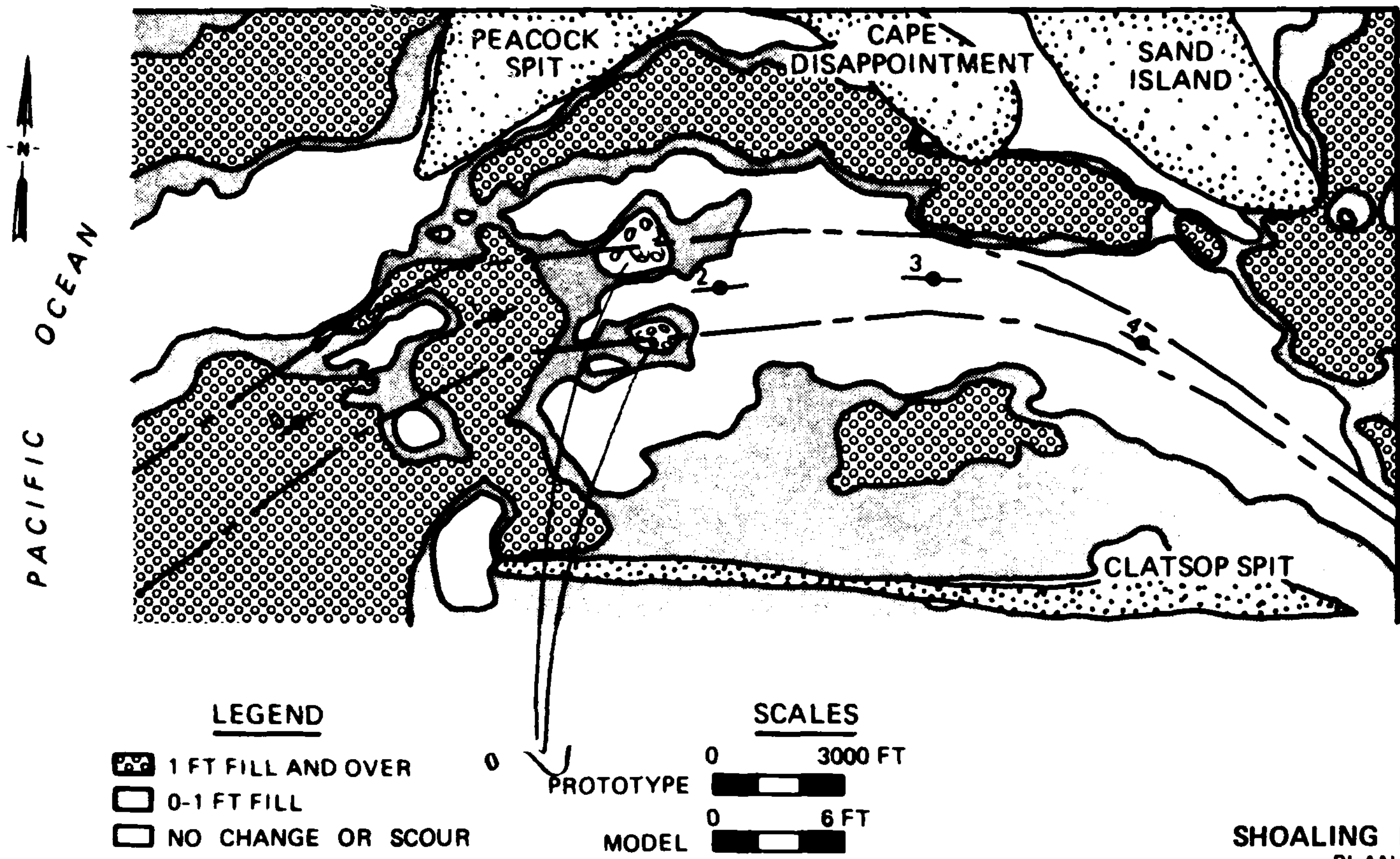
DISTRIBUTION OF MODEL DREDGING VOLUMES
COLUMBIA RIVER ENTRANCE
2-FT OVERDEPTH
PLANS A0, A1, AND A2



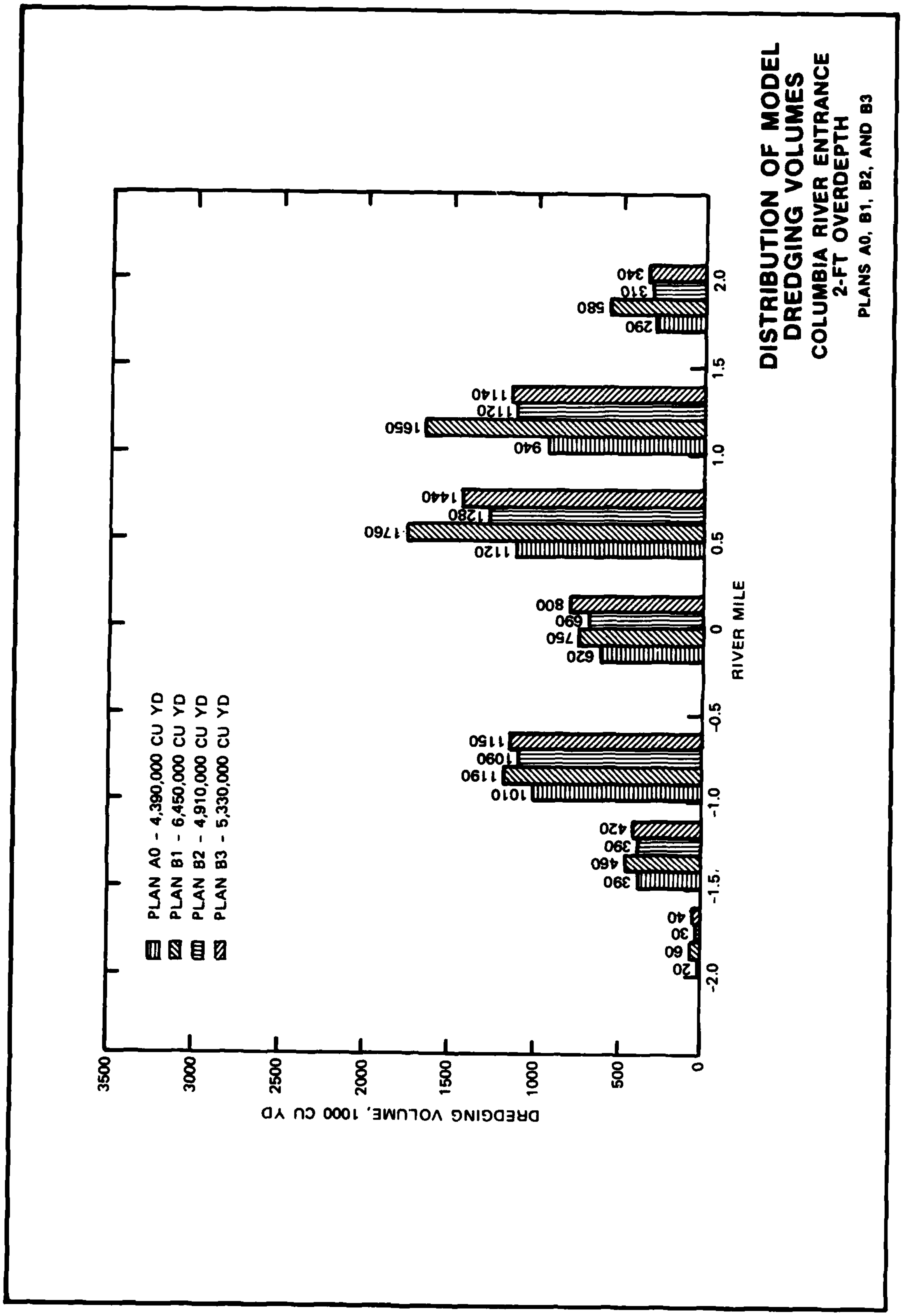
SHOALING PATTERN
PLAN A0



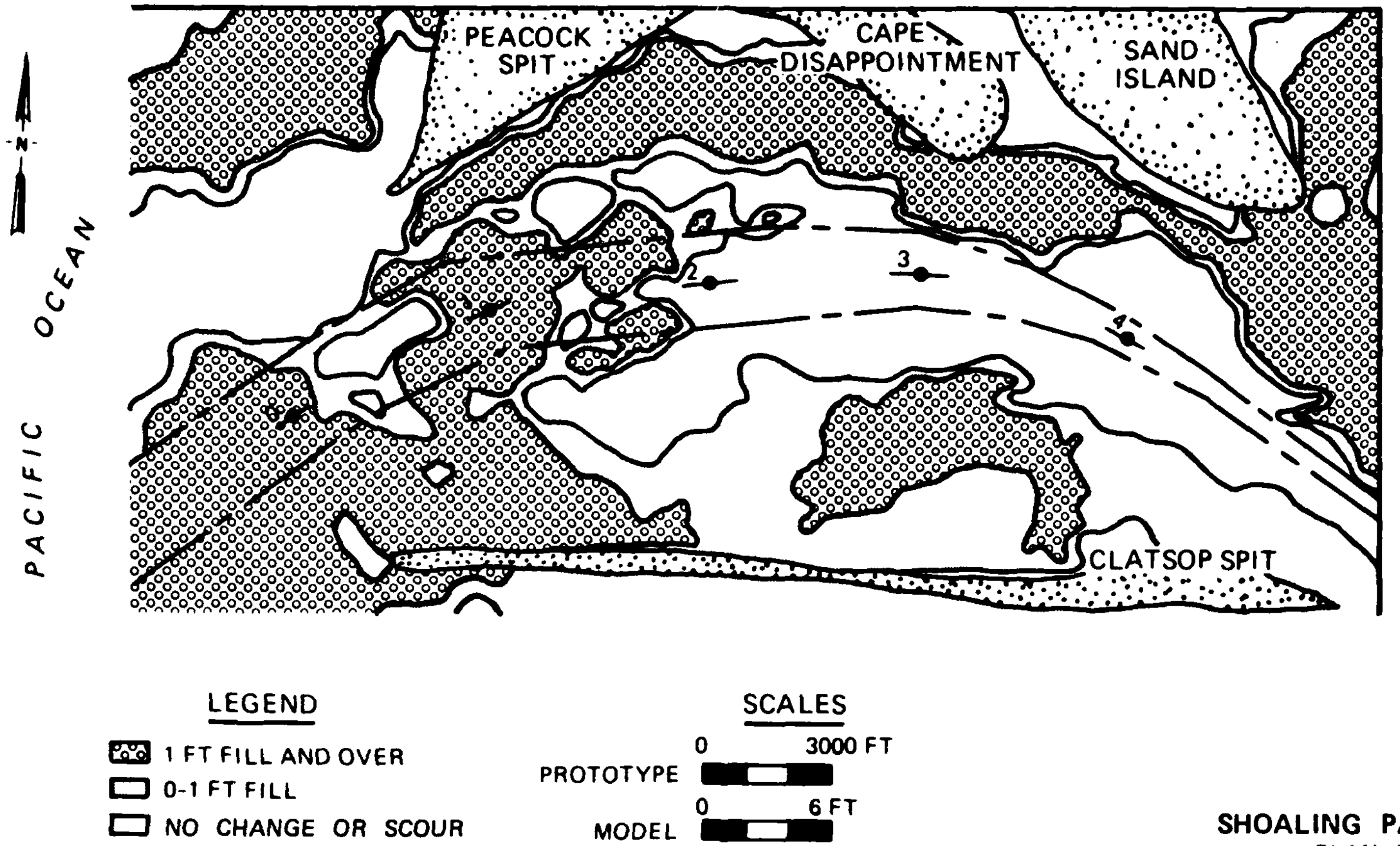
SHOALING PATTERN
PLAN A1



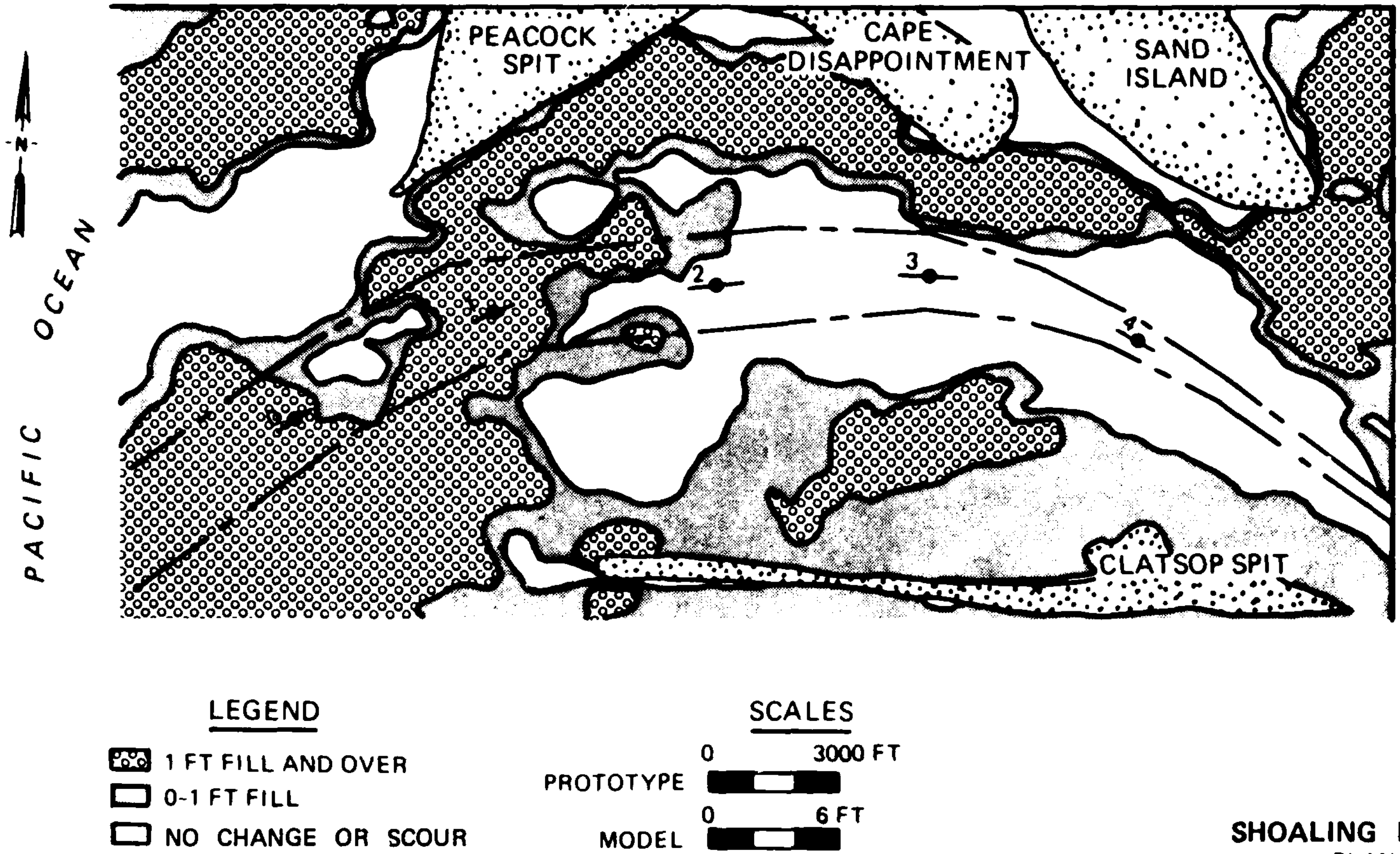
SHOALING PATTERN
PLAN A2



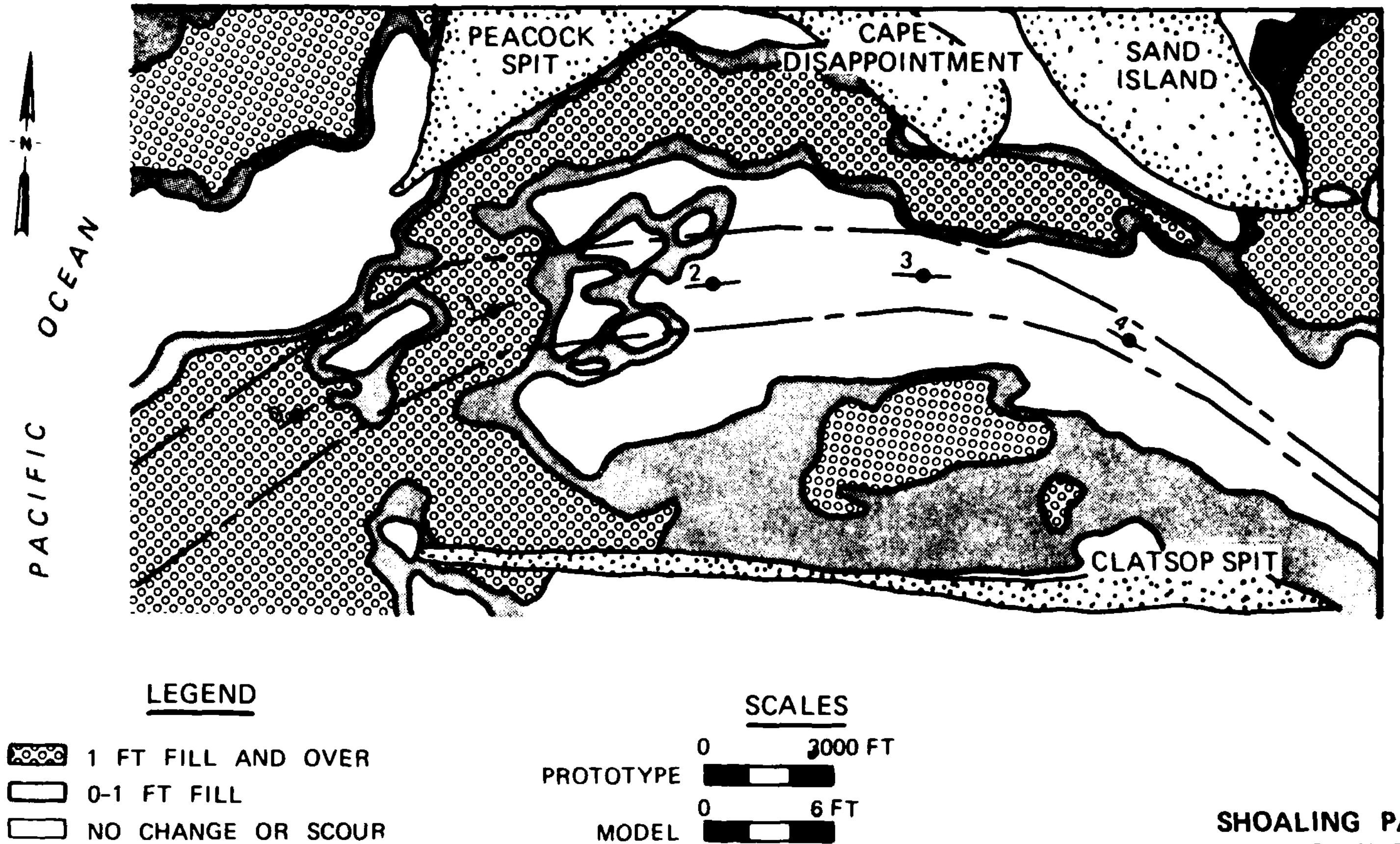
DISTRIBUTION OF MODEL
DREDGING VOLUMES
COLUMBIA RIVER ENTRANCE
2-FT OVERDEPTH
PLANS A0, B1, B2, AND B3
PLAN A0 - 4,390,000 CU YD
PLAN B1 - 6,450,000 CU YD
PLAN B2 - 4,910,000 CU YD
PLAN B3 - 5,330,000 CU YD
DREDGING VOLUME, 1000 CU YD
RIVER MILE
0
500
1000
1500
2000
2500
3000
3500
-2.0
-1.5
-1.0
-0.5
0
0.5
1.0
1.5
2.0
20
60
30
40
390
460
390
420
1010
1190
1090
1150
620
750
690
800
1120
1760
1280
1440
940
1650
1120
1140
290
580
310
340



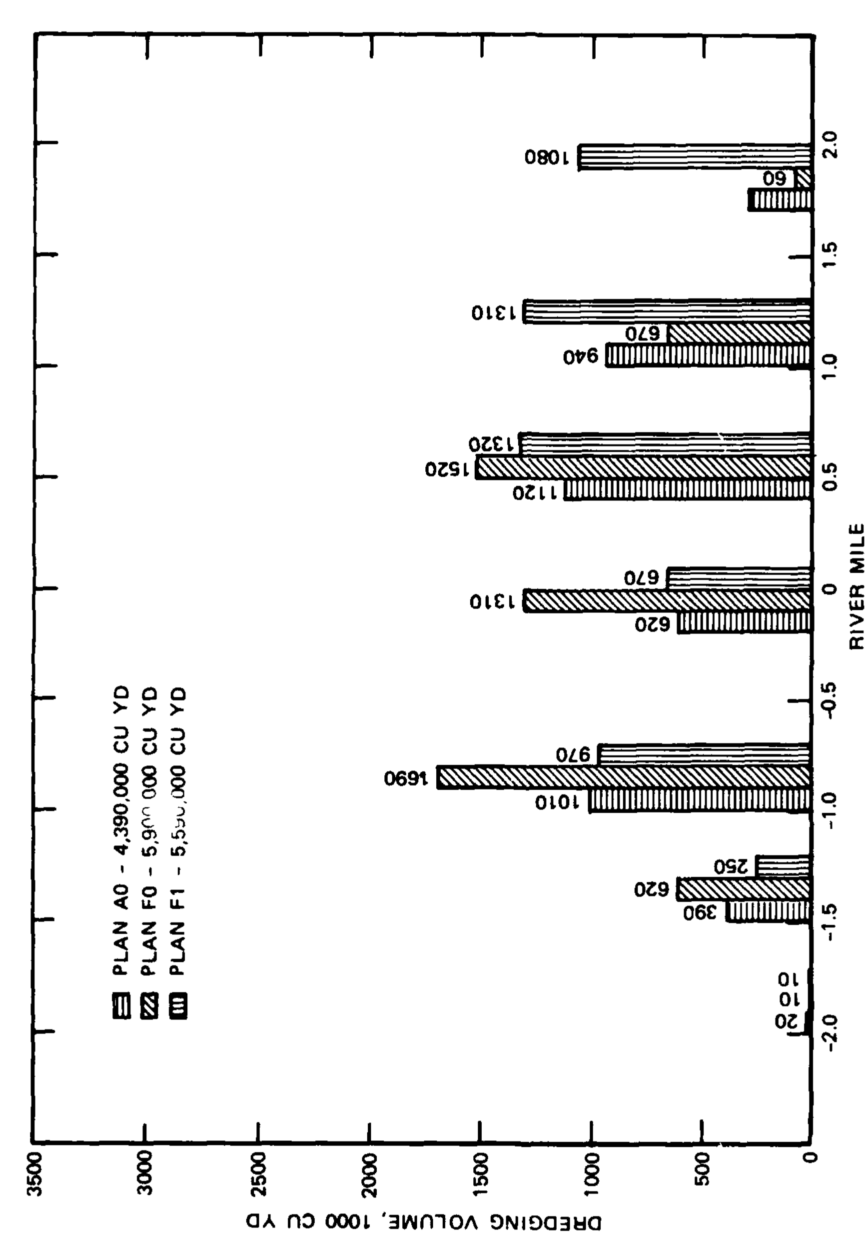
SHOALING PATTERN
PLAN B1



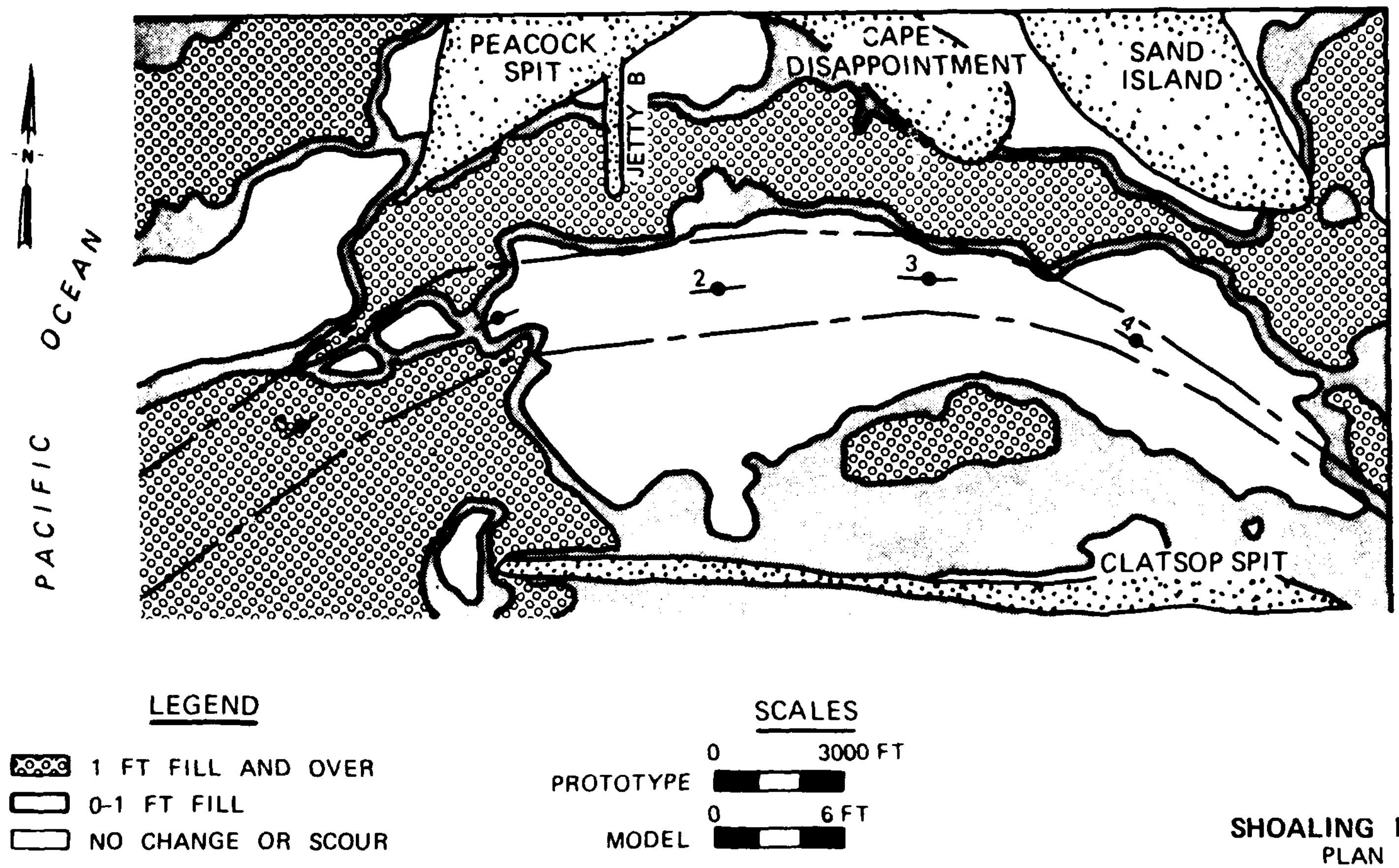
SHOALING PATTERN
PLAN B2



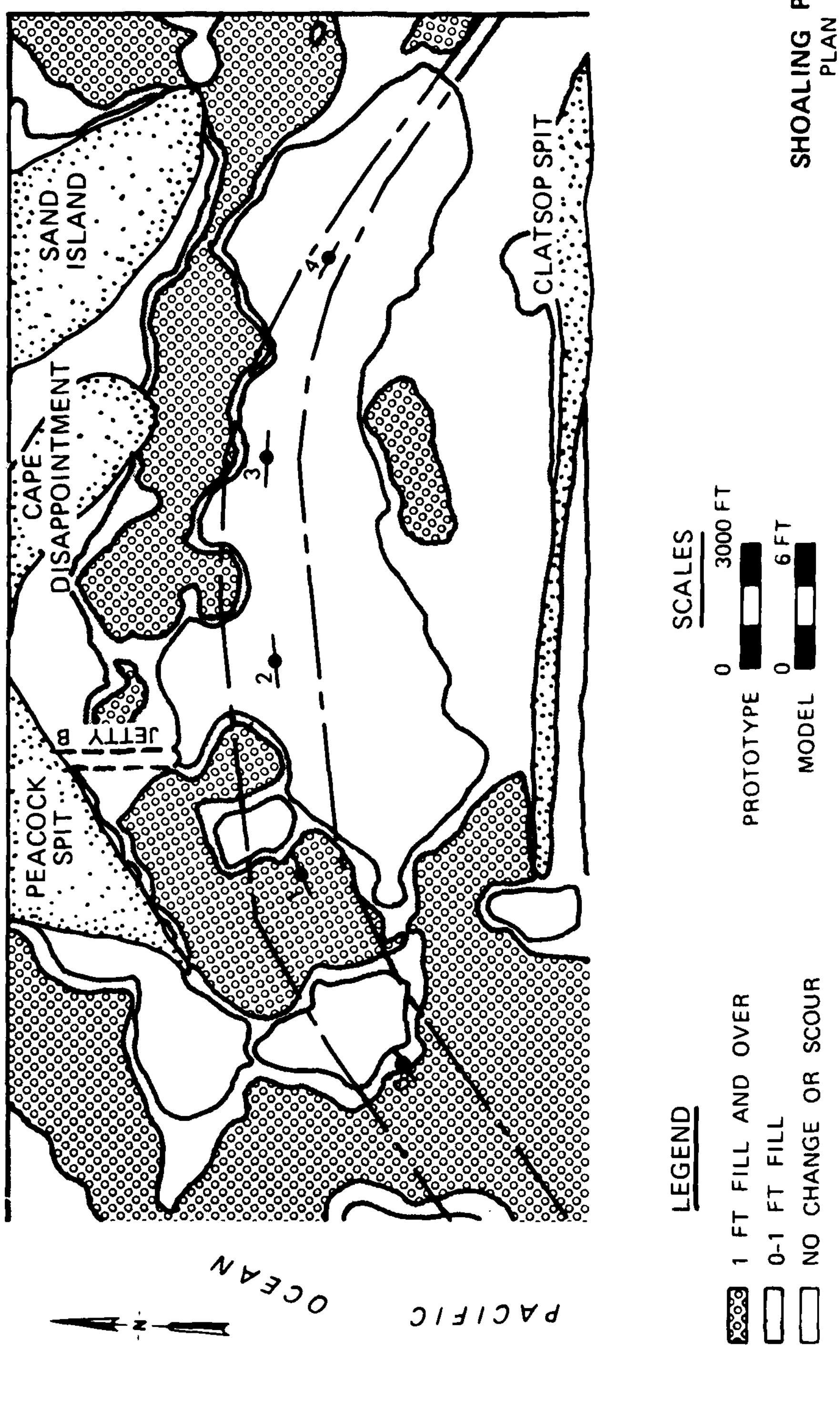
SHOALING PATTERN
PLAN B3



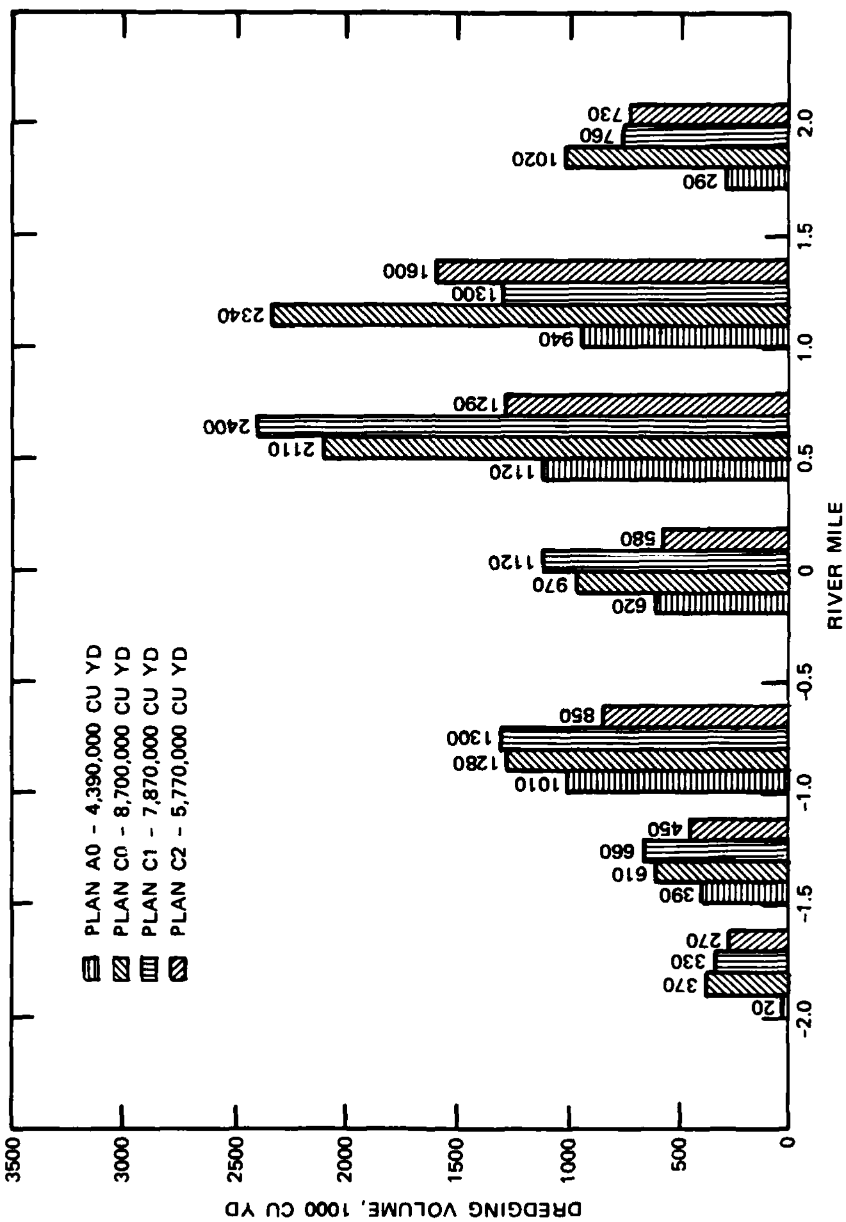
DISTRIBUTION OF MODEL DREDGING VOLUMES
COLUMBIA RIVER ENTRANCE
2-FT OVERDEPTH
PLANS A0, F0, AND F1



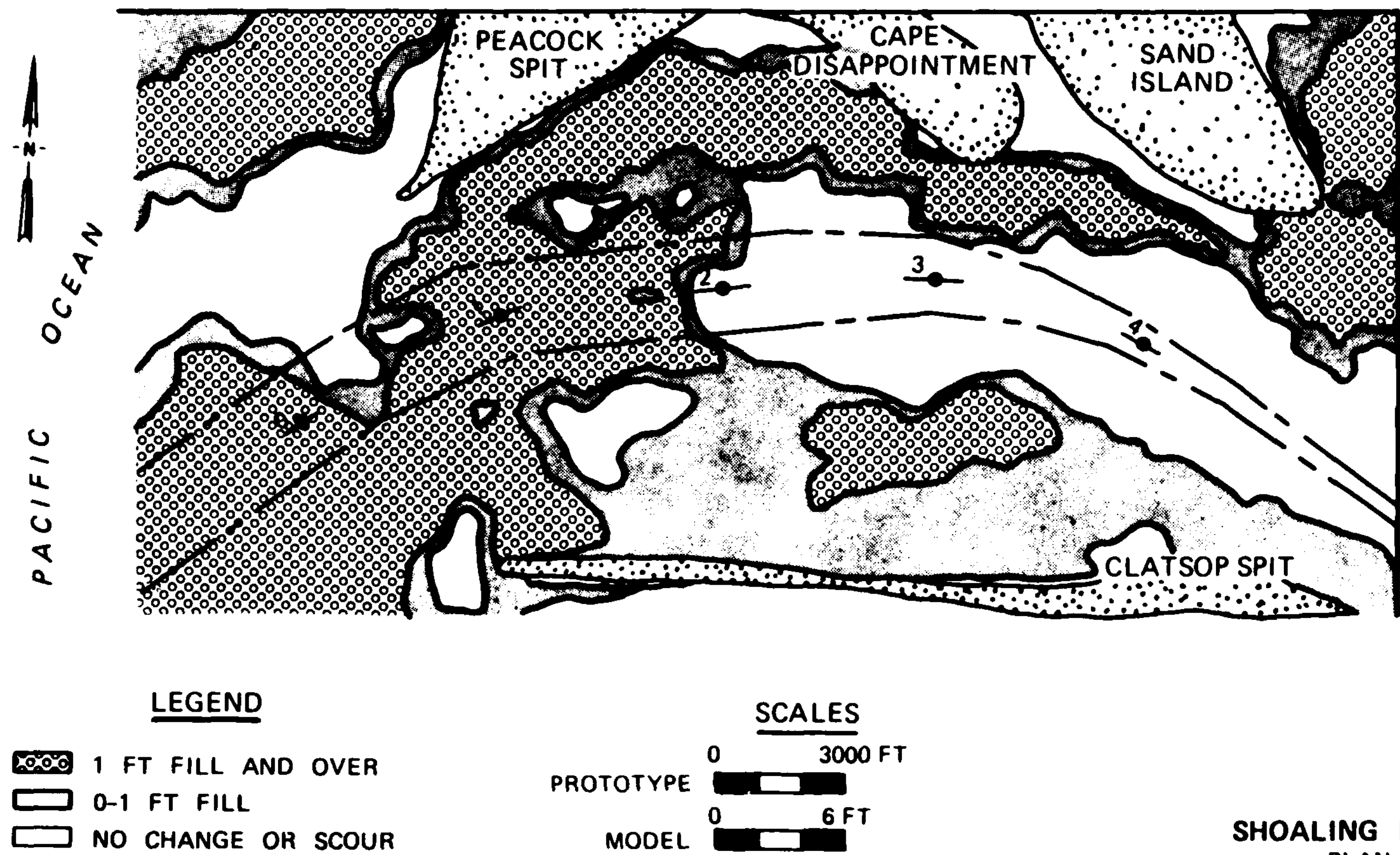
SHOALING PATTERN
PLAN F0



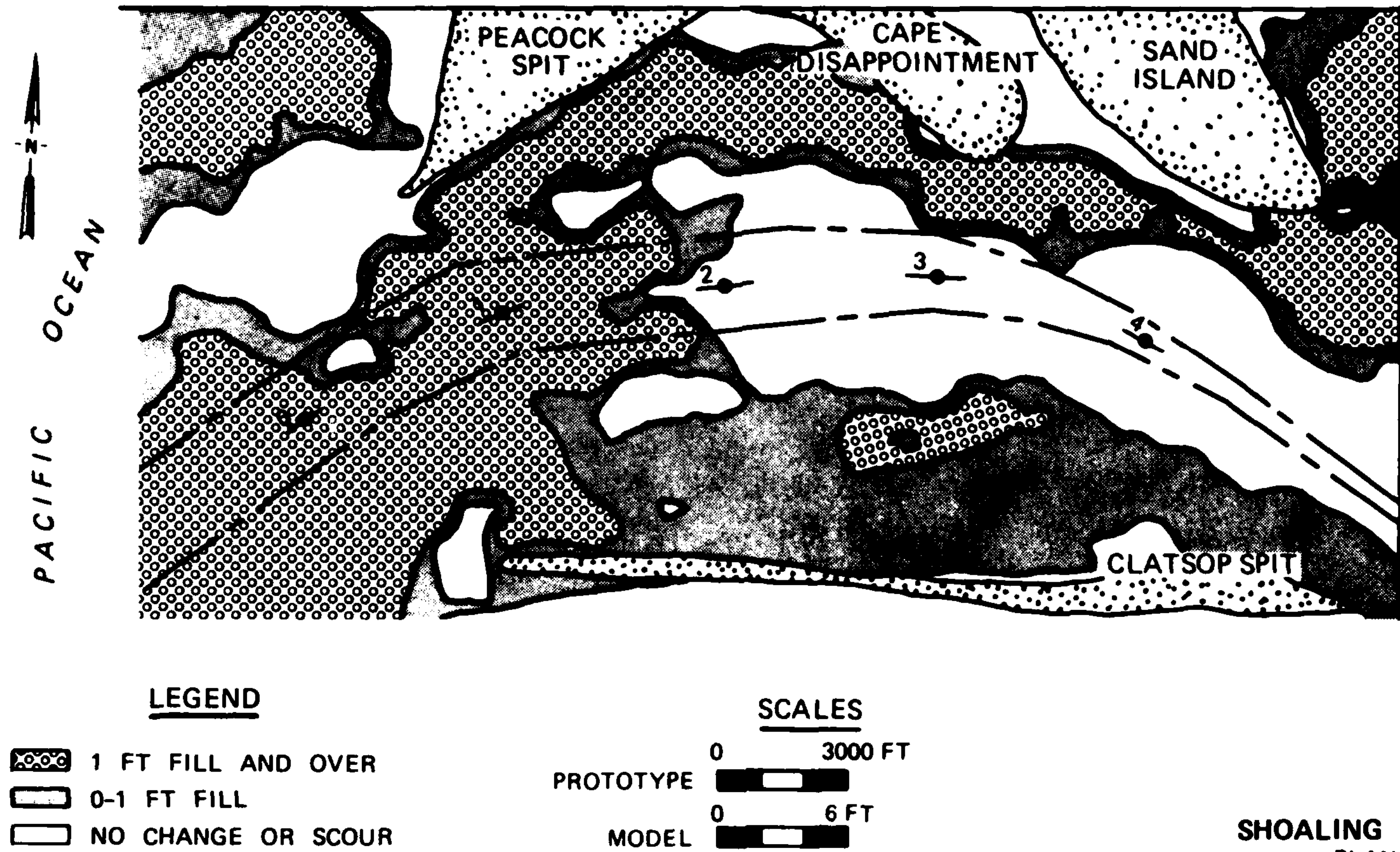
SHOALING PATTERN
PLAN F1



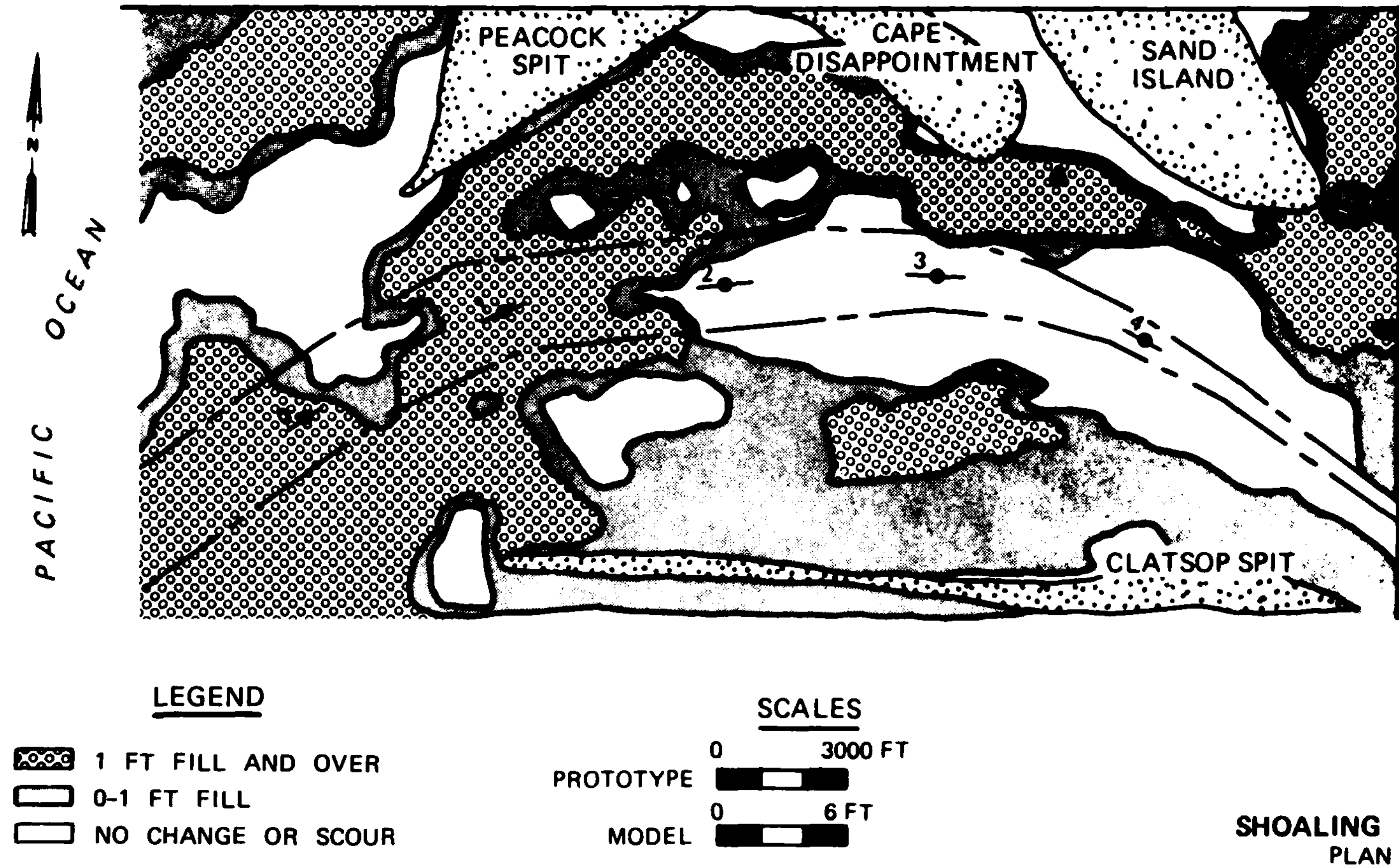
DISTRIBUTION OF MODEL DREDGING VOLUMES
COLUMBIA RIVER ENTRANCE
2-FT OVERDEPTH
PLANS A0, C0, C1, AND C2



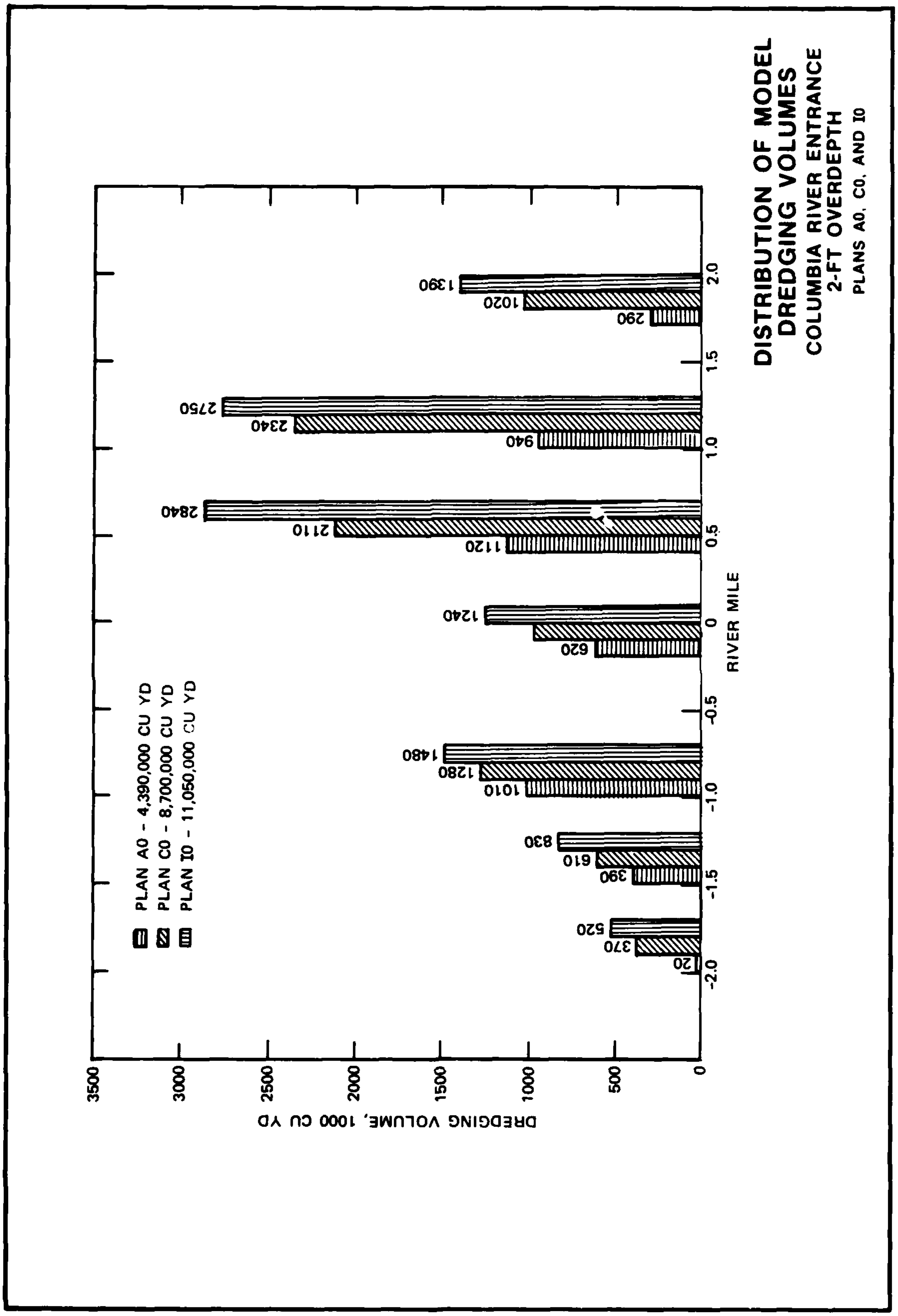
SHOALING PATTERN
PLAN CO



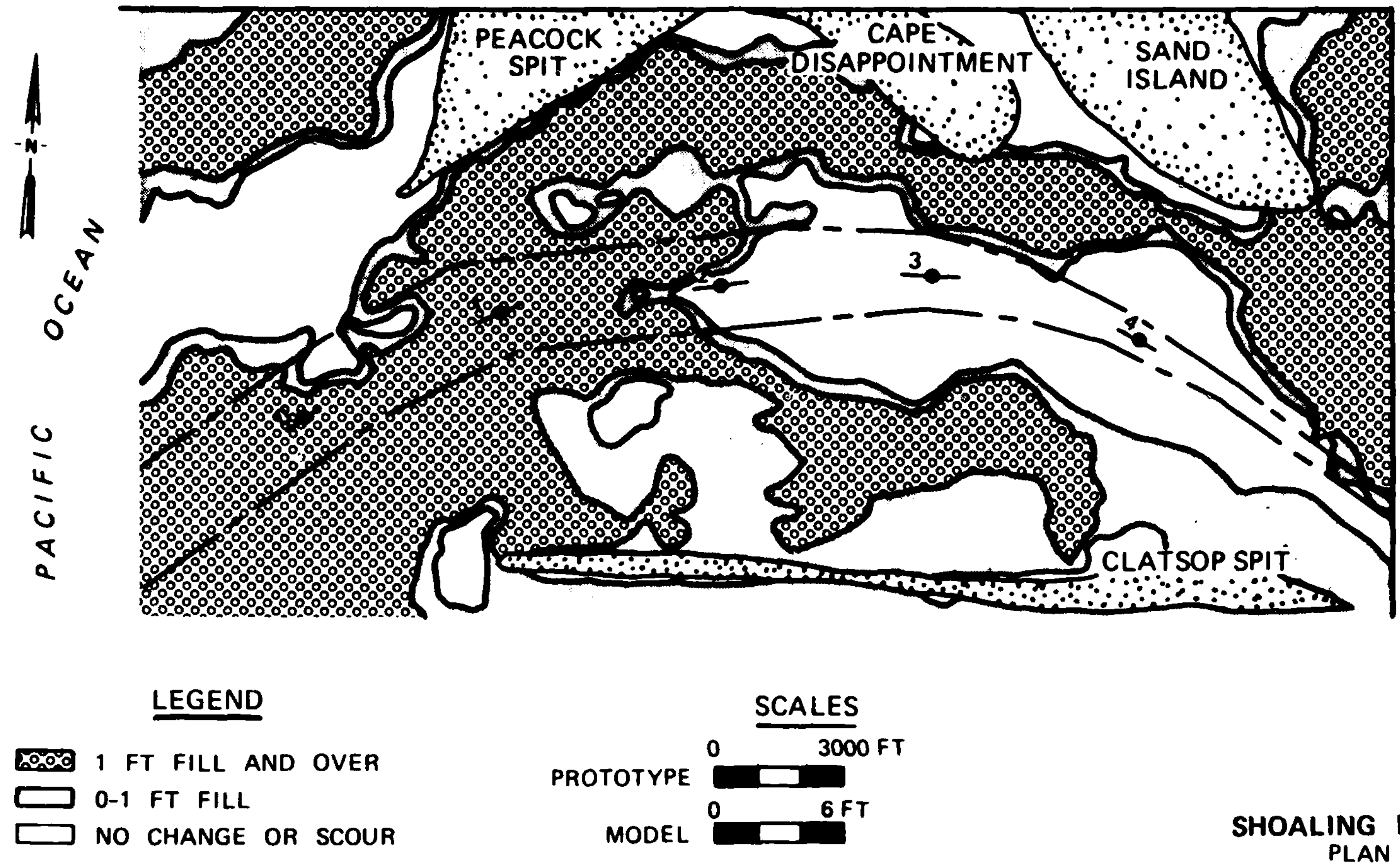
SHOALING PATTERN
PLAN C1



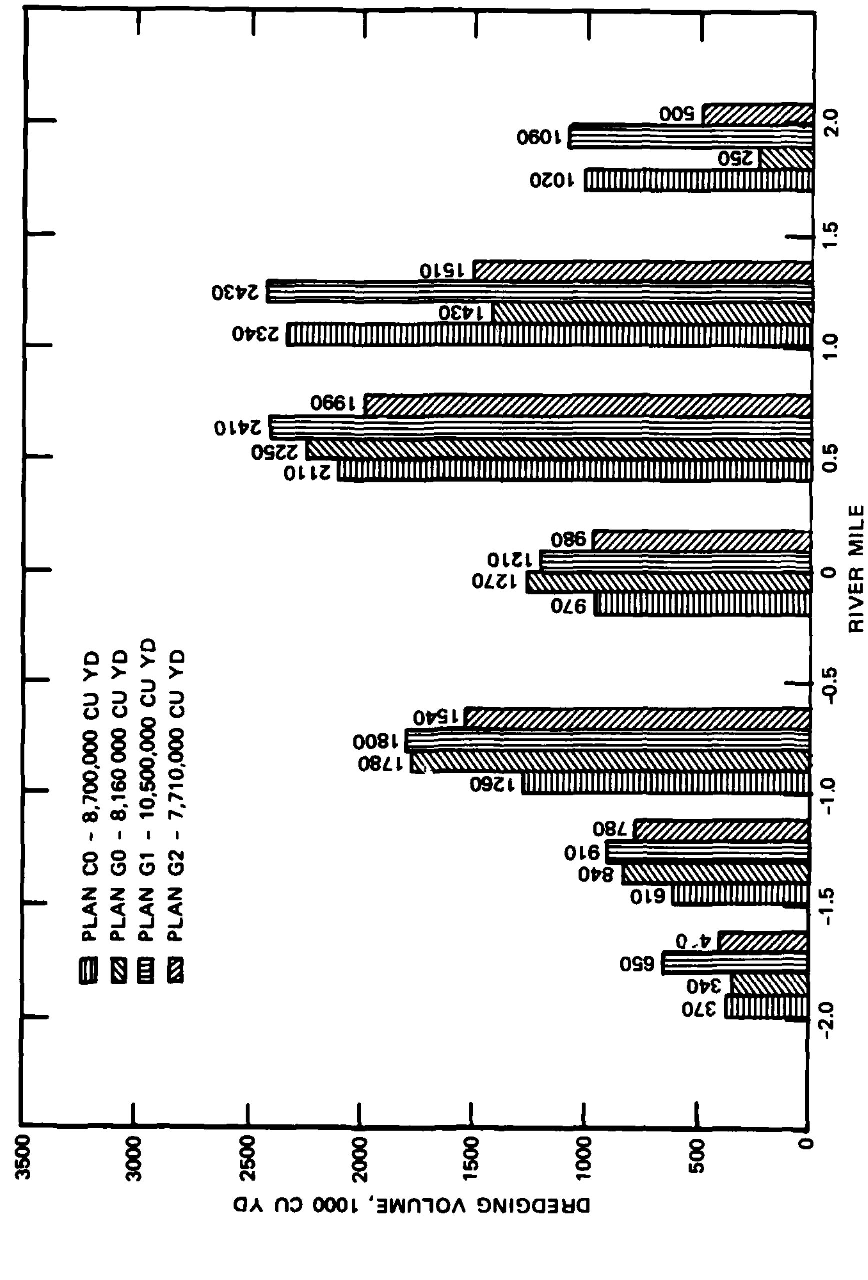
SHOALING PATTERN
PLAN C2



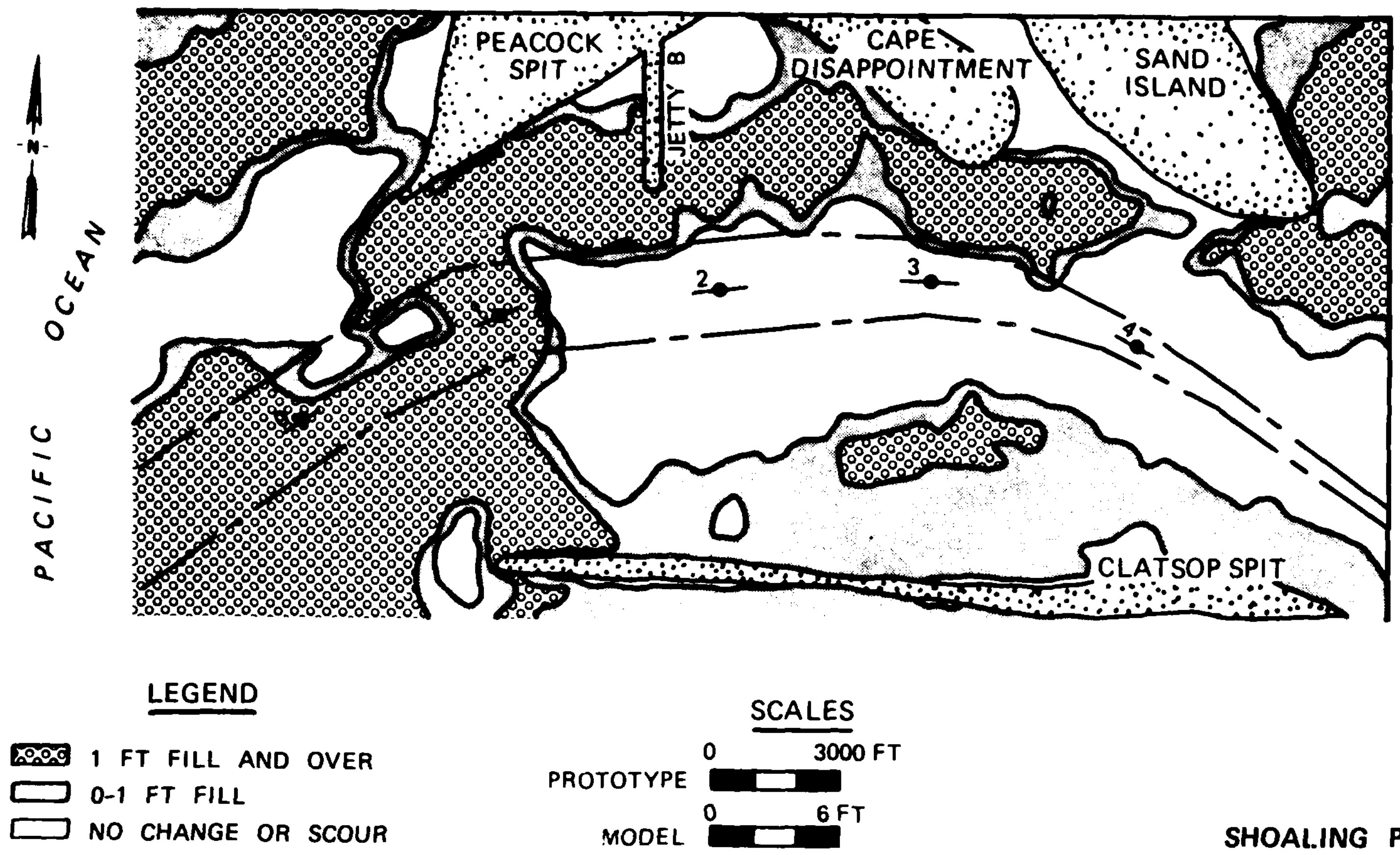
DISTRIBUTION OF MODEL DREDGING VOLUMES
COLUMBIA RIVER ENTRANCE
2-FT OVERDEPTH
PLANS A0, C0, AND I0



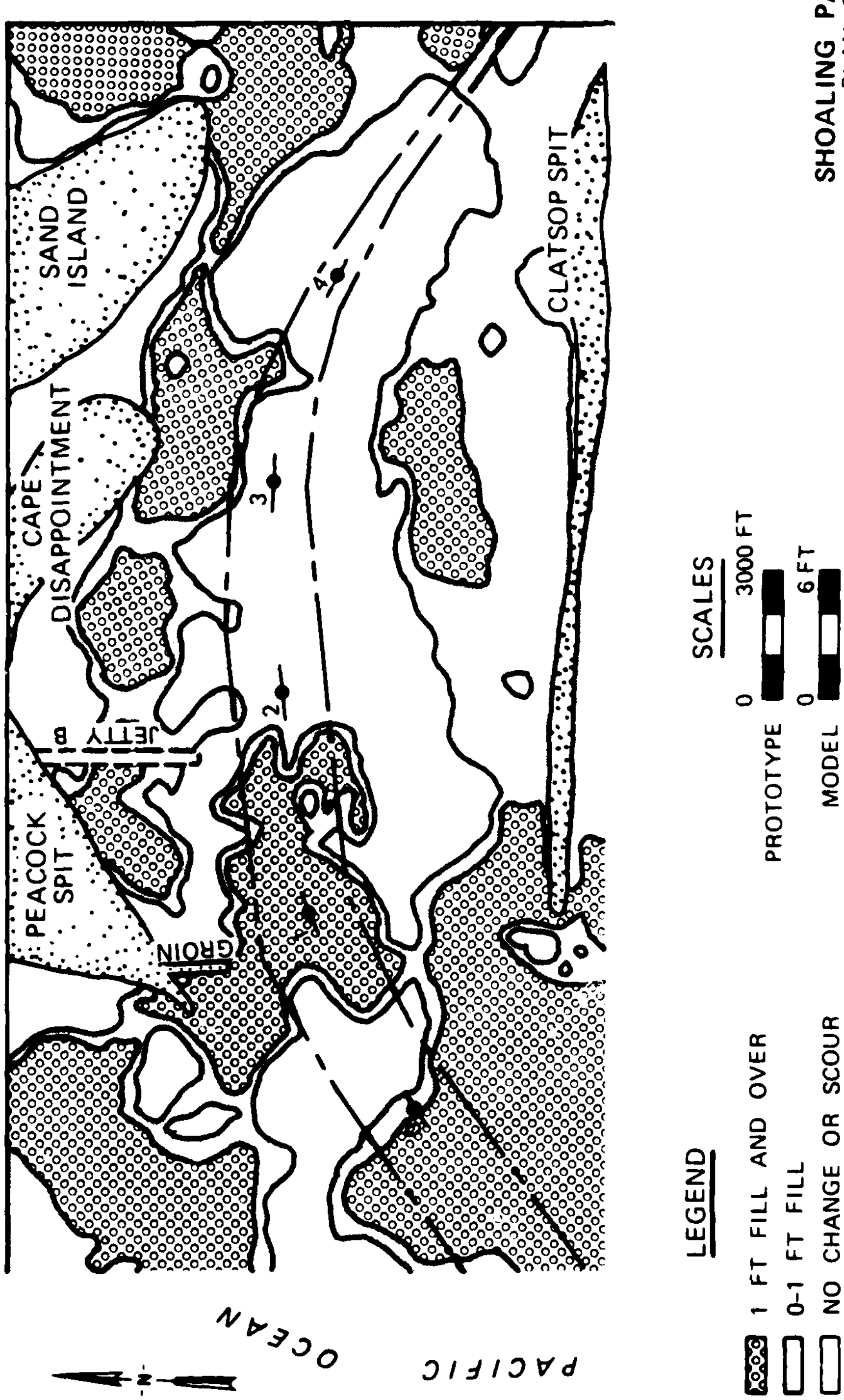
SHOALING PATTERN
PLAN 10



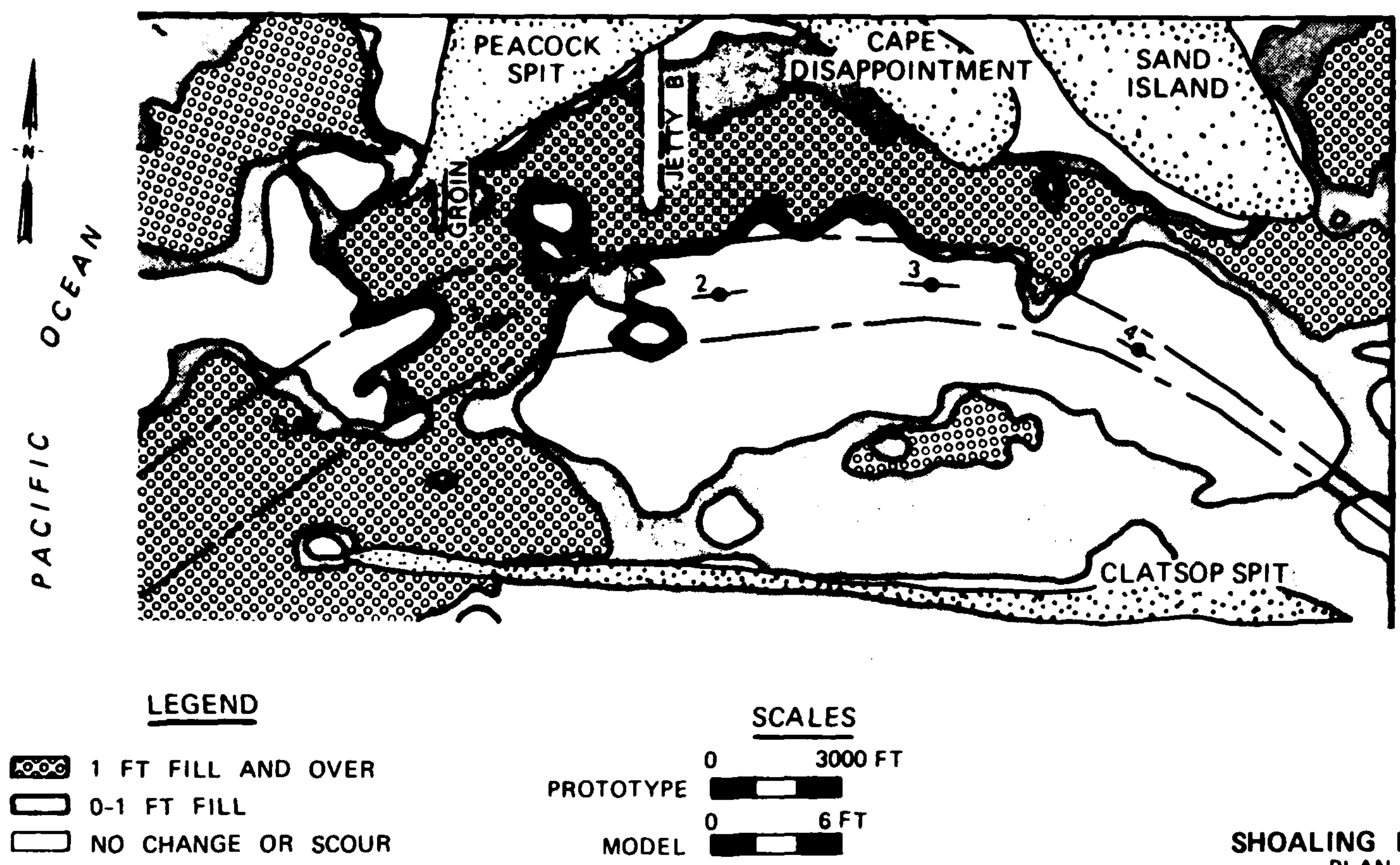
DISTRIBUTION OF MODEL DREDGING VOLUMES
COLUMBIA RIVER ENTRANCE
2-FT OVERDEPTH
PLANS C0, G0, G1, AND G2



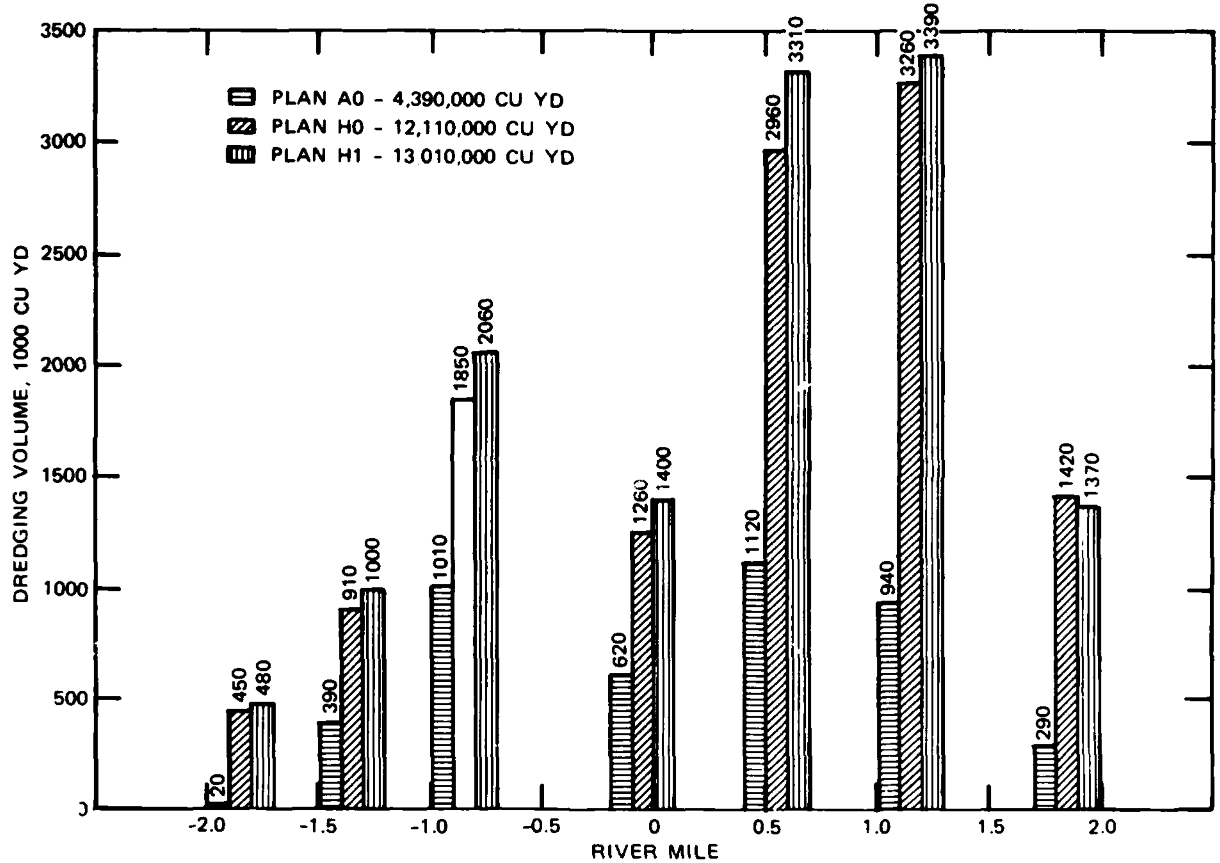
SHOALING PATTERN
PLAN G0



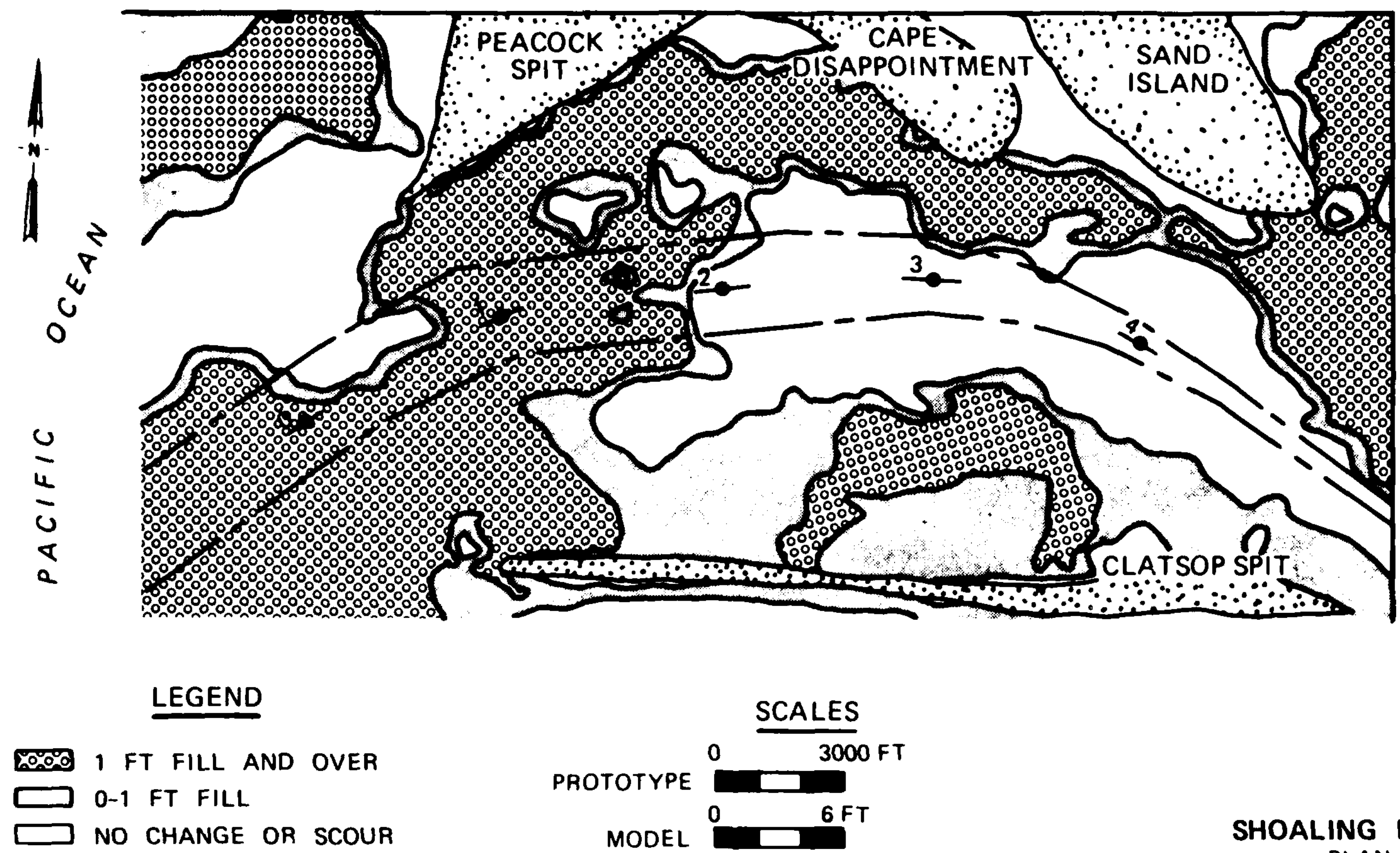
SHOALING PATTERN
PLAN G1



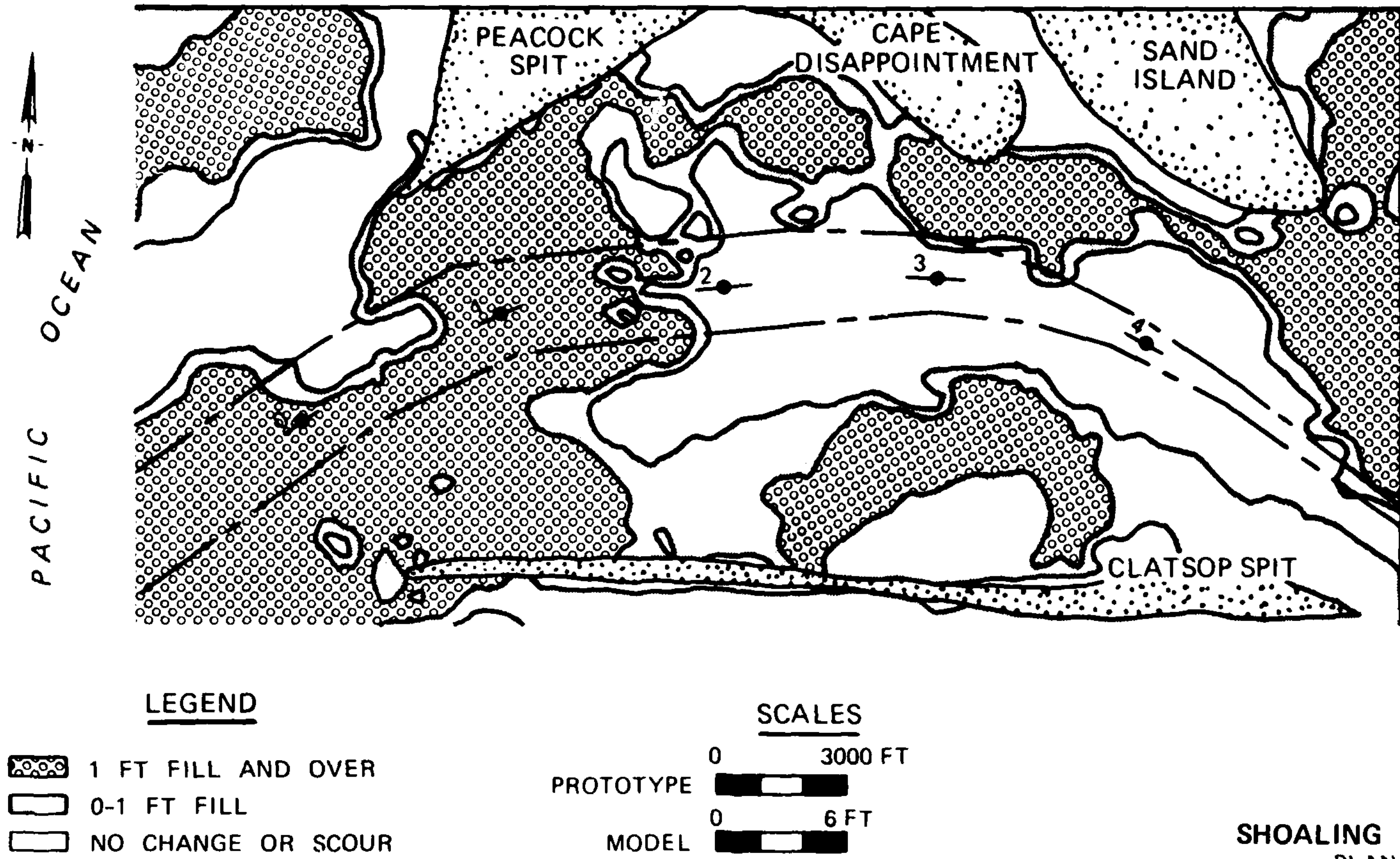
SHOALING PATTERN
PLAN G2



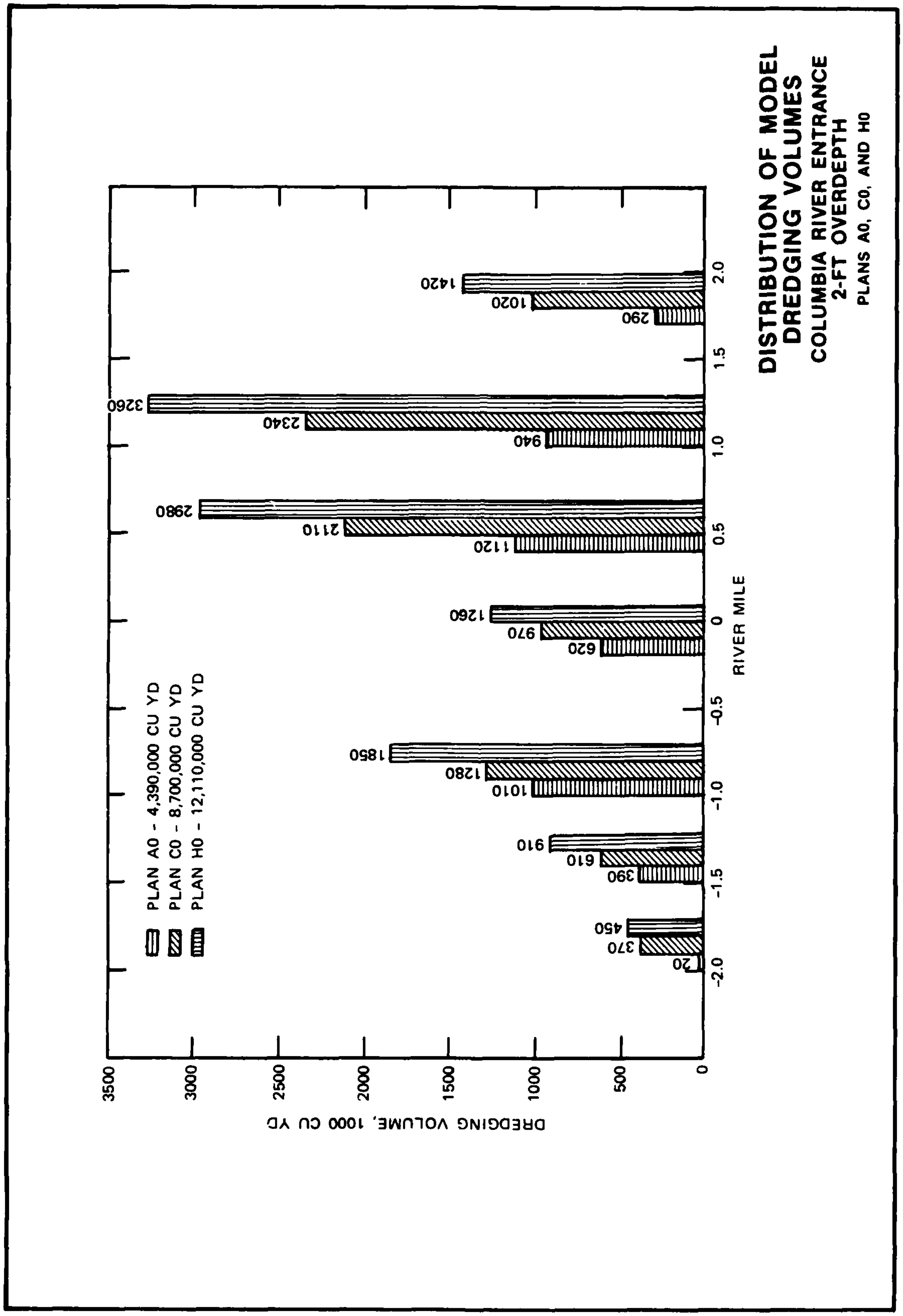
DISTRIBUTION OF MODEL DREDGING VOLUMES
COLUMBIA RIVER ENTRANCE
2-FT OVERDEPTH
PLANS A0, H0, AND H1



SHOALING PATTERN
PLAN H0



SHOALING PATTERN
PLAN H1



DISTRIBUTION OF MODEL DREDGING VOLUMES
COLUMBIA RIVER ENTRANCE
2-FT OVERDEPTH
PLANS A0, C0, AND H0

END

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